THE PORTMAN VARIATIONS:
A CRITICAL APPROACH TO ENTELECHY I MEDIATED BY SHAPE MACHINE

A Dissertation
Presented to
The Academic Faculty

by

Heather Michelle Ligler

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Architecture, College of Design

Georgia Institute of Technology
DECEMBER 2020

THE PORTMAN VARIATIONS:
A CRITICAL APPROACH TO ENTELECHY I MEDIATED BY SHAPE MACHINE

Approved by:

Dr. Athanassios Economou, Advisor
School of Architecture
Georgia Institute of Technology

Dr. Dennis Shelden
School of Architecture
Georgia Institute of Technology

Dr. Daniel Cardoso Llach
School of Architecture
Carnegie Mellon University

Dr. George Stiny
School of Architecture and Planning
Massachusetts Institute of Technology

Dr. Christina Crawford
Art History Department
Emory University

Date Approved: October 19, 2020

“Portman’s most characteristic buildings are totally Portman.”

Ada Louise Huxtable, 1974

“A NOBLER want of man is served by nature, namely, the love of Beauty.

The ancient Greeks called the world κοσμος, beauty. Such is the constitution of all things, or such the plastic power of the human eye, that the primary forms, as the sky, the mountain, the tree, the animal, give us a delight *in and for themselves*; a pleasure arising from outline, color, motion, and grouping. This seems partly owing to the eye itself. The eye is the best of artists.”

Ralph Waldo Emerson, 1836

ACKNOWLEDGEMENTS

This has been such a long, fabulous, catharsis – and many, many people contributed to this dissertation. First, thank you to my advisor, Athanassios Economou, who brought life to this work on many levels. I will always remember my first semester of graduate school as the beginning of a new journey that started with a pure love of shapes, design, architecture, and computation. I am thankful for our ongoing and never-ending conversations, a shared sense of humor, and your belief in me. You helped me accomplish so many of my dreams that I had to start imagining new ones! George Stiny, your work provides the roots for all of this delight in seeing and doing. Your insights came at critical moments and your belief in "the critic as artist" challenged me to see anew – and over and over again (still working on $x \rightarrow x$) – thank you. Christina Crawford, you showed up at just the right time and your perspective has revived the critical practitioner in me. You helped me bring my voice forward and you've motivated an interest in novel platforms to share the research – many thanks. Thank you, Dennis Shelden, for contextualizing my work within a broader discourse on computation in architecture. Your comments and questions challenge me to see the disciplinary value in my work – and you always bring the champagne! Daniel Cardoso Llach, you generously came on board with a fresh set of eyes that saw new connections that could be made across the work – and especially to the profession. Moreover, your thoughts on how to represent the work have jumpstarted conversations on sharing the research with a broader audience, thank you.

My work has been generously supported by research and teaching opportunities at the School of Architecture, College of Design at Georgia Institute of Technology. First, thank you to the Shape Computation Lab. Thanos, James, and Kurt: this work would not

happen without you and the many long discussions that we've had while this research was in progress. Thank you for your collaboration - you are my partners and dear friends. I'm excited for the rest of the work we have to do! Thank you to the Architectonics in Greece and Italy program for many years of delight and inspiration. Thanos, Laura, Libero, Yanni, James, Russell, Kerry-Gaye, and all the students who have participated over the years, thank you for reminding me how design impacts our lifestyle, joy, and sense of beauty at every scale. Thank you to Scott for hiring me to teach – and to all of my studio students for challenging me too. Lars, Michael, Alan, David, Jude, Charles, Fred, Harris, Annie, Michelle, Jonathan, Danielle, Vernelle, Tarek, Ryan – it is a joy to work and learn with you.

Additional support came from many places. My time at John Portman and Associates (now Portman Architects) had a profound influence on this work. To the late Jack Portman, many thanks for always being willing to meet with me to answer any question and discuss any curiosity I brought to the table. You always showed up to support my work and that spoke volumes – thank you. Grace Tan, you promoted me and gave me the opportunity to take on bigger challenges in the office – I learned so much from you. Luca and Norris – you are friends and mentors that I am lucky to know and collaborate with. Your conversations and advice and laughs are always with me! Thank you also to John, Walt, Gordon, Kelly, Sarah, as well as Andy and Paige at The Portman Archives for your support in the research. Mauro, Hao, Haldun, and Hanyun, we were in the trenches together and this work has constantly reminded me of your friendships, frustrations, and joys, thank you! My visiting semester with the Design Computation Group at MIT provided interlocutors, friends, and collaborators, thank you to Athina, Asli, Paloma, Dina, and Alex. Residency at the Hambidge Center provided room for work and a community for discussion that refreshed the project – thank you to my fellow fellows. And at Georgia

Tech, our ConCave group gave me ongoing support. Thank you to Hayri, Yousef, Memo, Gustavo, Zorana, Marisabel, James, and Kurt. Anna and Jeff – thank you for your friendship! Lastly, thank you to my new colleagues at Penn State and the Stuckeman Center for Design Computing – I'm so happy to start this next phase with y'all.

My friends and family keep me grounded – this work is for you. First, to Mark, Jackie, Rob, Arjun, and Jenn: your unconditional love and interest in my growth spurs me on. You instilled in me a love of people and of place that never leaves. Thank you for always helping me find the silver lining and for celebrating every victory, great and small. Most of all, thank you for not totally freaking out when I left the "security" of the profession to follow my heart! To my extended family and friend-family – Ligler, Russ, M-Town, AU, GT, I love you all. To the Posse - Mary Margaret, Amy, Tatum, Tina, and Jenny, I am thankful for the ridiculous joy you bring to my life, for premature celebrations, and for our longstanding friendships. Andrea, Amy, and Reema – I rely on our shared histories, design humor, and perspectives. Molly and Susan, you fed me more times than I can count, you make me laugh, and you keep me honest, thank you. Melissa, our calls always lift my spirits and our adventures keep me on my toes – thank you for constant encouragement and random hilarity. Beth and Jimmy, you always have the two things I need most: wisdom and a stocked bar – thank you for sharing both, ensuring that a fine time is had by all.

Finally, thank you to John Portman. I learned so much from you and working in your office. Your work is fascinating – it still speaks - and you gave me the freedom to interpret it all on my own terms. I remember when I passed my exams and got my architectural license that I felt a huge sense of relief and accomplishment – that I had *arrived* in some way. Your response was to remind me that "it's only the beginning of a great life" – and you were right, it is!

TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

John Portman's work is perplexing and polarizing. Characterized by his atria that captivate the popular imagination and his hybrid practice as architect-developer that redefined skylines throughout the world, but also ambivalently caricatured and dismissed for these same moves, the question of his impact remains blurry. This tension in Portman's assessment has been described as paradoxical and in fact, a closer look at the scholarship on his work reinforces this as an ongoing condition – one that highlights the challenges of interpreting the work. Yet, Portman's own imaginative account of his practice emphasizes another perspective. In reflections throughout his life, he referenced his 1964 house, Entelechy I, as the generator informing his entire corpus and the key design to understanding his architectural principles across all scales and programs.

The research here takes on the productive myth of Entelechy I – and its presumed adaptable and repetitive logic – as the impetus to develop a shape grammar on the plan of the house. This grammar is then the basis for generating variations that address the transformation of spatial relationships in the house revisited for other design contexts. Significantly, this two-stage procedure is mechanically (and automatically) implemented in *Shape Machine for Rhino*, a new shape grammar interpreter developed at the Shape Computation Lab (SCL) in the School of Architecture, Georgia Institute of Technology. Subsequently, the implementation of the Entelechy grammar reproduces the design of the original house and a series of new designs too – here proposed as Portm-Inoes to systematically recontextualize the house as a postmodern reinvention of Corbusier's Dom-Ino. In addition, the corresponding adaptation of parts of the grammar under different predicates yields transformation grammars that generate a series of plans at various

scales to interpret Portman's broader corpus of interior, hospitality, urban, and residential designs.

The contributions of the dissertation are: a) a critical compilation of perspectives on John Portman encompassing various interpretations that have remained so far distinct including connections to the Aristotelian and Emersonian philosophical underpinnings of the work; b) a formal approach to interpret Entelechy I in an automated shape grammar; c) a series of implemented transformation grammars that further redescribe Portman's architectural language in interior, hospitality, urban, and residential designs; d) an assessment of Portman's work derived by correlating the predicates, transformations, and shape rules in the grammars with fundamental aspects of design including the use of Platonic geometries, self-similarity, figure-ground reversal, boundary ornamentation, offset forms, and their combinations; and e) the setup of a constructive cycle of design propositions and evaluations achieved in *Shape Machine* to mechanically execute line drawings in an automated environment.

CHAPTER 1. INTRODUCTION

There was no client. The building was a speculation built with a giant void. Unconventional for Atlanta standards, it stood out as the tallest structure downtown with a blue-domed rotating restaurant on top. After multiple rejections from potential hotel operators all over the country, the building found a partner in the Pritzker family,[1] who saw the atrium hotel as a catalyst for their Hyatt House[2] brand:

> As native Chicagoans, it's not surprising that our family was keenly aware of architecture, living in the birthplace of the skyscraper, a city filled with buildings designed by architectural legends such as Louis Sullivan, Frank Lloyd Wright, Mies van der Rohe, and many others … In 1967, we acquired an unfinished building which was to become the Hyatt Regency Atlanta. Its soaring atrium was wildly successful and became the signature piece of our hotels around the world. It was immediately apparent that this design had a pronounced effect on the mood of our guests and attitude of our employees. While the architecture of Chicago made us cognizant of the art of architecture, our work with designing and building hotels made us aware of the impact architecture could have on human behavior. So in 1978, when we were approached with the idea of honoring living architects, we were responsive. Mom and Dad … believed that a meaningful prize would

[1] "After talking to Hilton, Sheraton, Loews, and Western, we finally sold the hotel to the Hyatt House Corporation, which had a chain of motels on the West Coast. They had never owned a big downtown hotel up to this time. That they were willing to make this move is due to the vision of the late Donald Pritzker and his uncle Jack and to their excitement about the possibilities. They came to Atlanta and immediately wanted to make a deal, and we made one fairly quickly." Portman and Barnett, 1976: 30.

[2] "The hotel opened to tremendous response from the public, to great success. It launched the Hyatt House chain into the big leagues and created the position that they now hold in the hotel industry as one of the largest chains in the United States." Ibid: 30.

encourage and stimulate not only a greater public awareness of buildings but also would inspire greater creativity within the architectural profession.[3]

The prize that the Pritzker family established in 1978 remains to date one of the highest international honors in the architectural profession. The unmentioned designer (and lead developer) of the client-less building - that both inspired the Pritzker Architecture Prize's mission toward "greater creativity" in architecture and became transformational for Hyatt's hospitality environments all over the world - was the architect-developer John Portman.

Portman's work has attracted both popular interest from those outside the architectural profession (like the guests and employees of the Atlanta Hyatt Regency) and resistance within the profession throughout his career.[4,5] The contrary and perplexing critical response to his work magnifies two grandiose moves: a) Portman's conflicting practice as a hybrid architect-developer; and b) his design of massive atriums and megastructures. In combination, the impressions of these predominant acts communicate

---

[3] As quoted by Tom Pritzker, the Chairman and President of Hyatt Foundation, whose parents founded the Pritzker Prize. The complete story is available at: "About the Prize," The Pritzker Architecture Prize, https://www.pritzkerprize.com/about

[4] Sylvia Lavin claims that Portman's difficult reception in the architectural community is indicative of the particular role of the academy at this time, "The academy had become the place that established the standards for importance … From the 1950s to the 1990s, there was an increasing distinction between success in professional terms and success in disciplinary terms, to the point that it became almost impossible for the two to exist simultaneously … Every moment that Portman succeeded in practice, he lost favor in the academy." Denny, P., 2018. Once Unfashionable, John Portman Is Being Seen in a New Light. *Metropolis,* https://www.metropolismag.com/architecture/john-portman-legacy/

[5] Arthur Drexler discusses the distance between an emerging critical profession in the academy and a practicing architectural profession during the late 1950s – 1970s more generally: "Critical discourse has shifted away from the profession. The most instructive commentary no longer comes from practicing architects who incidentally teach, and whose comments are interesting because their work commands admiration, but rather from academics who may or may not be architects, or architects who build, and for whom critical discourse is regulated by its own laws of production and distribution. Within this network, the connoisseur's cultivation of sensibility yields to what might be called technical gossip; aesthetics is seen as philosophy, and philosophy is seen as an examination of the structure of meaning, but not necessarily of what is meant." Drexler, A.,1979. *Transformations in modern architecture*. Museum of Modern Art: New York: 4.

a motivation that foregrounds commercial concerns a priori.

Portman's direct engagement with capitalist development alongside the anti-urban reading of his inward-facing atria subsequently imply that an architectural or urban sensibility is a lesser or even absent concern of the work. Not to mention that the story takes place in the heart of the South, a region in the United States largely stereotyped as well – by backwards conservatism and unsophisticated cultural production.[6] Altogether, the loudness of this caricature has distracted, even blinded, from the subtlety and value in Portman's work – a point that Peter Cook of Archigram[7] made over fifty years ago[8] but that nonetheless remains,[9] calling out the unresolved challenges of interpreting the

[6] For an example on the national caricature of Atlanta (and the South more generally speaking), consider *The New Yorker* cover from July 22, 1996, which commemorates the 1996 opening of the Olympic Games in Atlanta with a central welcoming host depicted as a man in overalls and a straw hat holding a pig in one arm, an Olympic torch in the opposite hand, and a diagonal banner labeled "HOWDY" across his chest.

[7] Archigram was an architectural group based at the Architectural Association in London in the 1960s known for their experimental neofuturist proposals, for example the 1964 project 'Plug-in-City,' a richly-illustrated design for a mega-infrastructure to support a whole city with interchangeable parts that "plug-in" with a kinetic system of cranes, reservoir tubes, and more to allow for constant change. Cook, P., 1999. *Archigram.* Princeton: Princeton Architectural Press.

[8] "The architect of the Peachtree Center and of the proposed Embarcadero Center for San Francisco is more than just a giver of form. He is managing partner of the group of developers on the San Francisco project. He is the admitted pusher, over a five-year period, of the Atlanta development. He has plans for more, and wisely does not disclose them all, in order not to raise land values. Such developers are rarely as imaginative as John C. Portman, and by wishing that he had more taste (our taste), or more discrimination (and to reject, maybe, the whole directness of the invention), we are throwing away his value to us. Our bland and unctuous determination has probably prevented some of the best twentieth-century building from ever happening." Cook, P., 1968. The Hotel is Really a Small City. *Architectural Design, 38(1),* 91.

[9] "The architect of the Peachtree Center and of the proposed Embarcadero Center for San Francisco is more than just a giver of form. He is managing partner of the group of developers on the San Francisco project. He is the admitted pusher, over a five-year period, of the Atlanta development. He has plans for more, and wisely does not disclose them all, in order not to raise land values. Such developers are rarely as imaginative as John C. Portman, and by wishing that he had more taste (our taste), or more discrimination (and to reject, maybe, the whole directness of the invention), we are throwing away his value to us. Our bland and unctuous determination has probably prevented some of the best twentieth-century building from ever happening." Cook, P., 1968. The Hotel is Really a Small City. *Architectural Design, 38(1),* 91.

[9] Karrie Jacobs recently described her view on Portman as one of "mixed emotions," concluding that, "whatever you think of him (I'd characterize my stance as tortured ambivalence) he was an original, the matchless impresario of a kind of placemaking that we may yet learn to value before

designs and their possibilities.[10]

1.1 From Paradox to Paradigm

What this all suggests is that another perspective – specifically, one with a very different methodology - is worth pursuing and may, in fact, be necessary in order to critically distill Portman's architecture from paradox to paradigm. Significantly, Portman points to a potential starting point for constructing a novel narrative on his work when he describes his 1964 house, Entelechy I, as the basis of his architectural philosophy (Portman and Barnett, 1976; Portman, 1997). To engage this possibility, this dissertation investigates John Portman's formal language from its origins in the design of a house, Entelechy I, to its adaptation in designs for interior, hospitality, urban, and residential plans. It argues that Portman's architectural philosophy, developed in his designs, necessitates a formal methodology to unpack its nuance in a way that can transcend the limitations of a single account or interpretation. The departure point for this inquiry is twofold: first, it considers the repetition in Portman's work as a design philosophy evident in his forms that can be analyzed independently to advance knowledge on his contributions; and second, it engages the generative approach to aesthetic criticism described in the shape grammar discourse (Stiny and Gips, 1972; 1978) as the method which can demonstrate this theory formally to generate and discuss possibilities of Portman's architectural language in an unprecedented way.

---

it's too late." Jacobs, K., 2018. Learning to Appreciate John Portman. *Architect Magazine: The Journal of the American Institute of Architects.*
https://www.architectmagazine.com/design/learning-to-appreciate-john-portman_o

[10] These challenges in interpretation are ongoing and will be discussed in detail in chapter 2 to elaborate the multiple characterizations established in the critical assessment of Portman's work to date.

Given the house as the self-proclaimed prototype in Portman's work and its unconventional domestic design, the research inquires on how this notion of flexible principles that can address designs with different scales, programs, and/or contexts can be understood in relation to the pieces, parts, systems, and logic of formal relations in the original project. More specifically, this is pursued through the second departure point of the research: by responding to the question of organizational adaptation through a methodology that is specifically interested in the power of shape as a representation that can facilitate more than one meaning in visual computation.

By engaging the house in its generative possibility through shape grammars, the research offers a constructive theory on Portman's architectural philosophy that can facilitate diverse interpretations by describing them as transformations in his broader corpus. The process begins by defining a shape grammar on the house that is further elaborated in relation to a diverse cross section of Portman's work. Building on this, the research develops a rule-based formal theory on Portman's architectural language that can connect Entelechy I with a series of subsequent projects that reinterpret the spatial logic of the house. In addition, by digging deeper into Portman's philosophical hobby and its potential relations to his adoption of the Aristotelian term 'entelechy' in his work, the research theorizes how these formal moves can be interpreted conceptually in the design philosophy inherent to his forms.

The project is contextualized within a disparate landscape of criticism and theories on Portman's designs that continue to grow in scope and, more recently, in detailed

scholarship as evidenced in two scholarly books that deal with aspects of the work.[11,12] Within this terrain, the dissertation extends the contemporary conversation on Portman by focusing directly on the formal and expressive possibilities of his work as a mechanism for new understanding. The research argues that the polar opposite responses to Portman's work are fundamentally related to his techniques and manipulations of form that are ambiguous in the sense that they can be read in at least two opposing ways and often many more. This approach provides a lens for defining Portman's contributions to American architecture after modernism within a visual, generative methodology that can reconsider the evolution of his forms – and speculate on their additional potentials.

1.2 A Computational Lens

In its methodology, the dissertation addresses the contemporary technological climate in architecture, where computation[13] has affected nearly every aspect of architectural design and production processes. From this perspective, Portman's description of Entelechy I suggests a rule-based methodology that can interpret liberal possibility within the parts and spatial relationships of a single design. Following this understanding, the research asks how shape computation can establish an architectural theory to assemble a discourse on Portman that has been dominated by partial and polarizing views. The key argument in this computational approach is that the visual nature of shape representations enable the diverse and plural interpretations inherent to human design processes – and that this can be modeled algorithmically with shapes. More

[11] Rice, C., 2016. *Interior Urbanism: Architecture, John Portman and Downtown America*. New York: Bloomsbury.
[12] Mostafavi, M. (Ed.), 2017. *Portman's America & Other Speculations*. Zurich: Lars Müller Publishers.
[13] Broadly defined in relation to the use of digital computers in the architectural design process, simply described as computer-aided design (CAD) or computer-aided architectural design (CAAD).

precisely, this is formalized through a generative description as modeled by the shape grammar discourse, where shape rules constructively advance the understanding of a language of designs (Stiny and Gips, 1972, 1978; Stiny, 1980a, 2006, 2015; Knight, 1994). The rule-based interpretation of the house is thus developed ask how the spatial relationships of a single design can serve as productive generators for a varied language of design possibilities in broader studies across Portman's larger corpus.

In an architectural context, shape grammars have demonstrated how visual, rule-based production systems can inform our understanding of a specific language of designs or a signature logic[14,15,16] and generate artificial designs in the same language (Stiny, 1977; Stiny, 1980b; Stiny and Mitchell, 1978; 1980; Knight, 1981; Knight, 1994; Flemming, 1981; Downing and Flemming, 1981; Flemming, 1987; Koning and Eizenberg, 1981; Buelinckx, 1993; Duarte, 2005; Phillips, 2008).[17] Significantly, the project here engages this algorithmic approach to formal analysis using *Shape Machine*, a new shape grammar interpreter for visual computation that allows designers to specify shape rules directly by drafting geometry. This is a radically new capability, as previous grammars on languages

[14] For an introduction on the formal concept of architectural "style" as a language of designs defined by a shape grammar, see: Stiny, G., 1985. Computing with Form and Meaning in Architecture. *Journal of Architectural Education, 39*(1), 7-19.
[15] A review on style and stylistic change in the arts that contextualizes the need for methods to address the formal aspects of style is given in Chapter 1, "Style and stylistic change: the tradition," in Knight, T., 1994. *Transformations in design : a formal approach to stylistic change and innovation in the visual arts*. Cambridge; New York: Cambridge University Press, 3-23.
[16] For an account on style that considers design process as a function of choices within a problem space that can be artificially modeled, see: Simon, H. A., 1975. Style in Design. In C. Eastman (Ed.), *Spatial Synthesis in Computer-Aided Building Design*. New York: John Wiley & Sons.
[17] These examples present theories on the designs of: Chinese ice-ray patterns; compositions with Froebel's kindergarten gifts; Andrea Palladio's villas; Mughal gardens; Japanese tea-rooms; Frank Lloyd Wright's Usonian houses; compositions based on Giuseppe Terragni's Casa Giuliani Frigerio; Bungalow houses in Buffalo, New York; Queen Anne houses in Pittsburgh, Pennsylvania; Frank Lloyd Wright's prairie houses; Sir Christopher Wren's church designs; houses in Álvaro Siza's Malagueira Residential District; and Louis Sullivan's system for ornamental design, respectively.

of designs in architecture have been primarily achieved with analog, manual computations or the hard-coded implementation of shape rules, including my own work.

Two initial studies on Entelechy I sketched an outline for a shape grammar (Ligler and Economou, 2015a) and a first attempt at implementation in *GRAPE for Rhino* (Ligler and Economou, 2015b).[18] The goal of this first phase was to achieve a three-dimensional shape grammar informed by a detailed analysis of the language of the house. This resulted in a proposal for the three-dimensional grammar that was achieved through manual shape computations drafted by hand that utilized various additional conventions to achieve the productions (Ligler and Economou, 2018). Following this initial work, the ideal next step was to implement this proposal in *GRAPE for Rhino* (Grasl and Economou, 2018), but this was only partially achieved. A series of shape rules were implemented, but ultimately this effort was abandoned because of the difficulties in achieving detailed results without significant hard coding of the algorithms and desired outcomes. The effort stalled when it seemed counter-intuitive to the analog process, losing much of the import and value of calculating with shapes that the manual process naturally allowed.

Nonetheless, this previous work aids in understanding the more general difficulties of computing with shapes. In the case of the analog work, the computations are enlightening conceptually, suggesting the explanatory and generative power of shape grammars in the context of Portman's work, but they should be considered as proof-of-concept given the drawbacks of manual calculations. These disadvantages include: a) errors, especially in complex designs where mistakes and oversights are more likely to

[18] *GRAPE for Rhino* is a plug-in for Rhinoceros by Robert McNeel and Associates. The software, developed by Thomas Grasl and Athanassios Economou, allows for three-dimensional shape rules to be implemented by encoding them directly in the scripting environment through conventional programming.

occur; b) difficulty understanding the computations so that the explanatory value of the grammar is underappreciated; c) the adoption of all sorts of conventions that increase the challenges of replication and/or reuse in another context; and d) fatigue in calculations by hand, leading to limited productive results and few iterations.

On the other hand, despite recent progress on shape grammar implementations in the last decade, the difficulty of achieving key concepts of shape grammar theory has continued to be a challenging area of research.[19,20,21] Specifically, the ability to represent a generous vocabulary of shapes and their parts to support emergence throughout a generative process, while also providing an intuitive interface on the frontend to allow designers to specify shapes, parts of shapes, and spatial relations on the fly has been especially unresolved (Eloy et al., 2018:131-132). Still, research in shape grammar interpreters at the Shape Computation Lab (SCL) at the School of Architecture, College of Design, Georgia Institute of Technology has covered much ground to date that has progressed the ambitions of the shape grammar community to achieve shape computations in a designer-friendly environment (Grasl and Economou, 2010; 2011; 2013; 2018). My first attempt at an implementation on the language of Entelechy I (Ligler and Economou, 2015b) worked within these developments, but demonstrated drawbacks that align with the general consensus on challenges in shape grammar implementations. In short, the work required substantial hardcoding on the backend and imposed geometric restrictions that limited possibilities of the grammar as the specifications were constrained

[19] The 2018 AI EDAM special issue on "Advances in Implemented Shape Grammars: Solutions and Applications" (Eloy et al., 2018) is the most recent published account on the current landscape of this research.
[20] For more background on shape grammar software, see Gips, 1999; Chase, 2002; Chau et al., 2004; Chase, 2010; and McKay et al., 2012.
[21] A state-of-the-art account that situates *Shape Machine* within research on shape grammar software to date is currently in press, Hong and Economou, forthcoming.

by the pre-defined sets of shapes indexed in the graph engine supporting the topological representation of shapes in the interpreter.

Given the difficulties of the previous work, the fact that all of the shape computations of this dissertation are automated in a new shape engine developed at the SCL, *Shape Machine for Rhino*,[22] extends the state-of-the-art profoundly – and especially from a designer's perspective. The newly enabled interpreter offers an unprecedented and robust environment for computing with shapes drawn directly in Rhino (Hong and Economou, forthcoming; Economou et al., 2019; Ligler and Economou, 2019b). Thus, the technology provides an entirely new way to consider formal analysis and synthesis as a rule-based, visual enterprise. Through its straightforward use of shape rules, the implementation empowers design research through the medium of drawing specifications rather than writing them, whether in hard-coded computer programs or the critical texts that characterize architectural theory to date.

In this sense, the dissertation marks a significant milestone not only in utilizing a general interpreter for shape computation as an interpretive medium – a technological challenge that, despite a number of research efforts, has been outstanding in the shape grammar community for nearly fifty years - but also in how it establishes a critical design theory based in visual computation. Related questions specific to the methodology that the research pursues include: a) What does the machine, as an interactive medium for visual design inquiry and the automation of shape rules, provide that furthers the discourse in comparison to analog grammars and other implementations?; and b) How can a rule-

[22] *Shape Machine for Rhino* is a plug-in for Rhinoceros by Robert McNeel and Associates. The software, developed by Tzu-Chieh Kurt Hong, Athanassios Economou, James Park, and Heather Ligler, is patent-pending. "Shape Computational Technology," US Patent Application No. 63/004,608. Filed April 3, 2020.

based methodology, supported by a novel technology, enhance architectural research, education, and practice more broadly speaking?

1.3 Contributions

The Portman Variations provides five primary contributions. First, it includes a critical compilation of perspectives on Portman's architecture encompassing various interpretations that have remained so far distinct. Second, it presents a formal approach to interpret Entelechy I in an automated shape grammar to develop a systematic understanding of the house. Third, it develops a series of implemented transformation grammars that further redescribe Portman's architectural language in interior, hospitality, urban, and residential designs, each adapted from spatial relationships identified in Entelechy I. Fourth, it provides an assessment of Portman's work derived by correlating the predicates, transformations, and shape rules in the grammars with fundamental aspects of design including the use of Platonic geometries, self-similarity, figure-ground reversal, boundary ornamentation, offset forms, and their combinations to convey an algorithmic interpretation of the architecture that proliferates beyond scale, program, or Portman. Fifth, the research delivers a prototype setup of a constructive cycle of design propositions and evaluations achieved in *Shape Machine* to mechanically execute line drawings in an automated environment, illustrating how shape computation can be applied as a productive, analytical, visual medium to enliven architectural theory through generative design descriptions.

1.4 Outline

The dissertation consists of six chapters. The first chapter introduces the project. The second chapter focuses on Portman's critical reception to date. The third chapter

presents a corpus of Portman's work as a curated selection for interpretation. The fourth and fifth chapters present a formal theory on Entelechy I and a series of studies on variations in Portman's language that connect spatial relations across the corpus to describe design principles that transcend scale and program. A concluding discussion of the research and future directions of the work provides a conclusion in the sixth chapter. More specifically, the chapters are:

1. *Introduction.* Chapter 1 initiates the research by describing the significance of Portman in the architectural discipline and the challenges in assessing his work. The shape grammar formalism is presented as the methodology that can facilitate more than one description through its visual computations, suggesting another way to engage Portman's architecture. An overview on the contributions and structure of the project is outlined to conclude the chapter.
2. *Portman's Paradox.* Chapter 2 discusses critical theories on Portman's architecture to elaborate the oppositions in interpretations of his contributions to date. The literature review is structured by a framework of four interpretations, each playing on Portman's hybrid dichotomy of the architect as developer. This assessment considers social and formal perspectives to emphasize the need for another approach to take on the uniqueness of Portman's designs.
3. *Coordinating Form.* Chapter 3 presents a series of designs from Portman's portfolio to define a corpus for closer study in the research. First and foremost in the discussion is Entelechy I, the house Portman describes as an ongoing guide for organizing principles in his work. Following the house, additional designs that address interior, hospitality, urban, and residential contexts are

introduced to provide a broader cross-section for interpretation in the research. To conclude the chapter, the concept of the Portm-Ino is postulated to suggest how Entelechy I might be discussed as a postmodern housing system, comparable to Le Corbusier's emblematic modernist take on domestic design, the Dom-Ino.

4. The Entelechy Grammar. Chapter 4 is focused on the generative specification of Entelechy I as described by a shape grammar on the house. The chapter presents the grammar step-by-step and rule-by-rule to unpack the production of the original design. Additional designs generated by the grammar are presented and discussed at the end of the chapter as Portm-Inoes. These designs revisit the idea of the house as a larger domestic system to demonstrate a series of design principles understood through the grammar and its productions. The Entelechy grammar aims to open up three questions on the house: a) Does the systematic architecture established in Entelechy I translate to other scales and contexts?; b) What principles of formal organization repeat in Portman's work – and can they be animated in shape rules?; and c) Can these findings provide additional critical insight on Portman's architectural contributions?
5. *The Portman Variations.* Chapter 5 expands on the lessons of the Entelechy grammar though a series of four transformation grammars that address the remaining corpus introduced in chapter 3. The transformation grammars elaborate on the theory on the house to test how spatial relationships translate from Entelechy I to interior, hospitality, urban designs that map to Portman's description of flexible organizational principles as well as to his second residence at Entelechy II, to revisit how the language of the first house informs

Portman's second house at the beach. Design variations produced by each transformation grammar further demonstrate the design principles established in chapter 4 to put forward a new theory on Portman's work.

6. *Conclusion.* Chapter 6 recapitulates the contributions of the dissertation in a brief discussion and outlines possibilities for future research. The chapter concludes with final notes on entelechy and a personal epilogue on the project.

CHAPTER 2. PORTMAN'S PARADOX

Initialized by the notion of the architect as developer, this chapter addresses the context of Portman's practice and its assessment in architectural criticism to date. By developing an understanding of American architecture after modernism and Portman's early practice within that landscape, the philosophical underpinnings of his work are postulated. Subsequently, the chapter assembles a series of hybrid characterizations to critically review the literature on Portman, laying the groundwork for a new approach that directly engages Portman's forms as a basis for interpretation.

2.1 American Form after Modernism

Portman's architecture is indeed perplexing: it is pragmatic and dazzling, attracting critique and admiration. The architect as developer, Portman is a maverick in the profession whose hybrid practice of architectural design and commercial real estate development was controversial in the 1960s and even in the 1990s was still considered a "self-administered Faustian bargain" (Koolhaas, 1995: 839). Nonetheless, its unorthodox production was appealing in Atlanta and across the United States at a time when the integration of divided spaces was a national concern, made explicit by the Civil Rights Act of 1964, prompting a necessary reconsideration of design at all scales, but especially in buildings and cities.[23,24]

[23] The civil rights leader, U.S. Congressman, U.S. Ambassador to the United Nations, and 55th Mayor of Atlanta Andrew Young discussed Portman's role in this scene as part of the Atlanta Action Forum (a biracial Civil Rights group of twelve white and twelve black leaders formed to improve race relations in the city) during his eulogy at Portman's memorial service, available at https://www.atlantamagazine.com/news-culture-articles/andrew-youngs-eulogy-john-portman/

[24] In this sense, Colin Rowe's argument that modernism in the United States was fundamentally different from its European counterparts because "the revolutionary theme was never a very

In fact, the 1960s and 1970s found many cities in the United States struggling economically and socially, but Atlanta's downtown seemed to be an exception.[25,26] By 1971, just four years after the Atlanta Hyatt Regency opened, guestroom demands continued to exceed expectations, prompting an expansion of the hotel. The Hyatt's new cylindrical Ivy Tower,[27] also designed by Portman, no longer had the spatial inefficiencies nor the excitement of the atrium, but it was strategically connected to the adjacent volume, providing guests with access to the interior space that had attracted visitors from all over the world. Just as construction was completed on the Ivy Tower, the Hyatt Regency O'Hare opened at Chicago's airport as the first export of Portman's hospitality work outside the South, thus initiating a growing national practice. Alongside this expansion, development progressed back home too as Portman's downtown project, Peachtree Center, took shape piece-by-piece with office buildings, restaurants, public plazas, and more, creating ongoing redevelopment in the heart of Atlanta. Peachtree Center gained national attention when *The New York Times* architectural critic Ada Louise Huxtable wrote about Portman as the man behind a "twentieth century urban phenomenon" – and his inventive model for American cities that was creating "a new kind of South," recognized in the mixed-use prototype revitalizing Atlanta's downtown (Huxtable, 1974).

The growth of Portman's practice and its exports continued from Chicago to San Francisco, Los Angeles, New York, Detroit, and back to Atlanta again. At times these

---

prominent component of American speculation about building" can perhaps be reconsidered. Rowe, C., 1972. Introduction to *Five Architects*. New York: Wittenborn.

[25] A detailed account on the city in this period is given in Chapter 3, "Atlanta, New American City," in Rice, C., 2016. *Interior Urbanism: Architecture, John Portman and Downtown America*. New York: Bloomsbury.

[26] A comprehensive view on Atlanta, covering the city's characteristic and successive campaigns of "organized redevelopment and promotion" from its founding through the 1996 hosting of the Olympic Games is given in Rutheiser, C., 1996. *Imagineering Atlanta: The Politics of Place in the City of Dreams.* New York: Verso.

[27] Now called the Radius Tower.

exports, which were predominantly hotel projects, were also part of extended urban transformations like what was initiated at Peachtree Center. In Atlanta, San Francisco, and Detroit, Portman experimented with his vision for the coordinate unit, an urban model he was developing,[28] alongside his argument for a pragmatic architecture foregrounding experience, nature, art, and the controversial bedfellow of commercial real estate development that enabled him to explore and build his ideas without theoretical inhibition. With a growing list of projects at a range of scales from the monumental atrium to the coordinate unit and beyond, Portman was experimenting with designs that addressed the intersection of cities, human experience, buildings, real estate, and more.

The moment was concurrent with the Civil Rights movement in America[29] and at the dawn of postmodernism in the architectural world, as the end of the 1950s marked the beginning of a transitional period in the discipline. This transition brought forward significant questions on what and how to build.[30] The 1960s and 1970s thus became a time of questioning the modern movement in architecture and the disciplinary task was one of "sorting out, developing, and transforming possibilities implicit at the beginning"

---

[28] "I have come to the conclusion that cities ought to be designed in a cellular pattern whose scale is the distance that an individual will walk before he thinks of wheels … If this area is developed into a total environment in which all of a person's needs are met, you have what I call a coordinate unit, a village where everything is within reach of the pedestrian. You could walk to work, school, church, recreation, shopping, entertainment, and so on without having to get into a car or any other kind of transit unless you were going outside the cellular unit." Portman and Barnett, 1976: 131.

[29] The years 1954-1968 mark the heart of the Civil Rights movement as defined by the 1954 U.S. Supreme Court ruling in Brown v. Board of Education that racial segregation in public schools was unconstitutional and the 1968 assassination of Dr. Martin Luther King, Jr.

[30] Reyner Banham's 1960 publication of *Theory and Design in the First Machine Age* asserted the failure of design in the First Machine Age (also known as the modern movement, the International Style, etcetera, as characterized by the work of Walter Gropius, Le Corbusier, Mies van der Rohe, and others) along with the proclamation that a Second Machine Age had commenced due to the fact that machines and machine products were now ubiquitous, affordable, and popularized for a broad, mass public rather than the elite that were the primary beneficiaries of the First Machine Age. Banham, 1960:10-11.

(Drexler, 1979:3-4).[31]

Portman's work in this initial period is an architectural response to all of these factors, providing an intriguing corpus for closer study. Despite much scholarship to date on Portman's contributions, his work has yet to be taken on in a formal way that can grapple with its diverse possibilities, repetitions, and contradictions. The critical scholarship on Portman's work largely reinforces his simplification as architect-developer, mega-builder, a partial narrative that has yet to engage how his forms – in their design moves and the spaces they create – invite, and perhaps even encourage, diverse views. Portman's characteristic interest in the proactive agency of the architect as well as his productive output of designs at a variety of scales supports a formal narrative that is challenging to assess precisely because of its plurality and the multiple interpretations it offers. The evolving design principles that motivated these formal commitments are underexplored too, especially in how they were initiated by a momentary encounter with Frank Lloyd Wright that instigated a grander vision for how Portman could contribute to American form after modernism.

2.2 Seek Emerson

In 1951, Frank Lloyd Wright came to lecture at the Georgia Institute of Technology in Atlanta.[32] This was a year after Portman's graduation from the School of Architecture at Georgia Tech, so he was ready and eager to practice following in the footsteps of the 20th

[31] Drexler goes on to summarize this initial period of disillusionment with an anecdotal vignette on Mies van der Rohe's impression at the time: "Thus in 1960, some months before his seventy-fifth birthday, when Ludwig Mies van der Rohe was asked to describe his working day he answered: "I get up. I sit on the bed. I think 'what the hell went wrong? We showed them what to do.'"

[32] Frank Lloyd Wright visited and gave a lecture at the campus of the Georgia Institute of Technology in Atlanta on October 22 and 23, 1951. Georgia Tech Alumni Association, 1951, *Georgia Tech Alumni Magazine*, *30*(02): 9.

century architectural masters including Mies, Le Corbusier, and most of all Frank Lloyd Wright. Portman was an emphatic storyteller and part of his personal folklore included a sustained effort to connect his architectural principles to Wright's, a story that started at the moment of meeting in Atlanta.

Portman purportedly asked Wright for advice on what it took to be a great architect. Wright's simple answer was to "Seek Emerson" (Portman, 1982). This direction from the master was taken seriously by the recent graduate, who began to read the works of Ralph Waldo Emerson in earnest. From this moment on, philosophical thought became an area of self-study that influenced all aspects of Portman's life, and especially his design ideas.

Wright's advice on Emersonian studies was not just given to Portman as a particular case, it was the standard direction passed on to all of his apprentices. Even more, he didn't suggest it as an entry text only, but he instructed his apprentices to read Emerson *every day*. In fact, Wright's commitment to the ideals of "The American Scholar," Emerson's 1837 address to the Phi Beta Kappa Society at Harvard College,[33] caused him to informally refer to the text as "our thesis in architecture" in his Sunday morning talks to his apprentices (Uechi, 2013). Wright's writings, talks, and designs allowed him to develop

[33] In "The American Scholar," Emerson called for a distinctively American cultural independence. The message was a plea to depart from the European influences that continued to perpetuate in society and a call to an American school of life. He was invited to give the talk after the success of his essay "Nature" published the year before where he laid out the foundations of Transcendentalism, his theory that advocated for self-reliance as the key practice to free the unique individual spirit of every man. This democratic approach to intellectual, spiritual, and cultural growth was anti-institutional, critiquing standards that absolve individual perception and putting responsibility on the individual to educate themselves. Three main points were included in "The American Scholar" to guide this pursuit: a) the study of nature; b) the development of the mind through the "mind of the Past" as expressed in literature, art, or any other form that could be examined; and c) the call to be speculative thinkers engaged in action, alert to the world's attractions, and committed to "the conversion of the world." Emerson, [1837], 2000.

this Emersonian directive toward his own creative production based in nature.[34] Wright described his developing definition for organic architecture with a cautionary disclaimer that the distinctive nature he was referring to was different from the biological meaning,

> If we have occasion to refer to the visible world, we will use the term 'External Nature.' The word 'Organic" too, if taken too biologically, is a stumbling-block. The word applies to 'living' structure – a structure or concept where features or parts are so organized in form and substance as to be, applied to purpose, integral. Everything [that] 'lives' is therefore organic. The inorganic – the 'unorganized' – cannot live (Wright, 1931).[35, 36]

---

[34] In "Self-Reliance," Emerson taught the drawbacks of routine imitation and disciplined consistency in personal thought and action, elevating spontaneous experimentation as a liberated state for exploration, evolution, and contradiction to understand and strengthen the intuition. While he admitted the misunderstanding that comes from this chameleon nature, he also questioned if that was really such a bad thing. His argument privileged "genuine action" as the self-explanatory alternative to conformity. This critique extended to all realms of imitative action, but most of all to the arts. The problem of conformity in the arts as Emerson conceived it was its foreign correspondence to the individual since he imagined conformity as the "traveling of the mind" to soils that were not native to an innate understanding. Emerson, [1841], 2000.

[35] Wright's conception of 'living' structure was instilled at an early age by the Froebel kindergarten method advocated by his mother, Anna Lloyd Jones Wright, who was an avid Unitarian interested in Transcendental thought. She delivered papers about Emerson's philosophy (Siry, 1996) and sought progressive models of education for her son. Guided by the Froebel method, Wright learned "the system … a basis for design and the elementary geometry behind all natural birth of Form" (Wright, 1957). While Emerson was the primary philosophical source for Wright's organic approach in architecture, Froebel's method provided a spatial counterpart to this instruction.

[36] Wright's mentor, Louis Sullivan, was also a crucial contributor to his evolving conception of the organic in architectural form. Sullivan's instructions to Wright as a young architect were to read Herbert Spencer and Walt Whitman. Spencer was not Wright's cup of tea, but both Sullivan and Wright shared an admiration for Whitman (Wright, 1949). Sullivan was so moved by Whitman's work that he even wrote a letter to the poet where he applauded his profound artistry that "can blend the soul harmoniously with materials" (Traubel, 1914). The seamless connection between the soul and the material that Sullivan recognized in Whitman's work made him a hero in how to achieve individual expression in artistic form. A key example of this artistry is found in Whitman's first piece from *Leaves of Grass*, 'One's self I sing,'

> One's-self I sing, as simple separate person,
> Yet utter the word Democratic, the word En-Masse.
> Of physiology from top to toe I sing,
> Not physiognomy alone nor brain alone is worthy for the Muse,
> I say the Form complete is worthier far,

Wright's living structure depended on the organic as an organizational approach to form, where parts are related for an integrated purpose. This notion of organic architecture informed all of Wright's works and his commitment to Emerson[37] above all as a guide and tutor makes clear the origins of this philosophical worldview.[38, 39]

> The Female equally with the Male I sing.
>
> Of Life immense in passion, pulse, and power,
> Cheerful, for the freest action form'd under the laws divine,
> The Modern Man I sing (Whitman, 1855).

Sullivan and Wright viewed Whitman, the Modern Man, as a "prophet" and an ally, developing his work in their shared democratic soil (Adams, 1957). According to Wright, Sullivan achieved this same organic identity in his architectural forms (specifically in the Wainwright and Guaranty Buildings) where "some proof of the oneness of spirit and matter came clear … the inevitable service of the artist-architect" (Wright, 1932). For Sullivan and Wright, the artist-architect worked to reveal this innate living principle by structuring architectural form in composition, a process that was akin to the artistry of the poetic arrangements that inspired their organic understanding.

[37] "Arising out of eternal reason, one and perfect, whatever is beautiful rests on the foundation of the necessary. Nothing is arbitrary, nothing is insulated in beauty. It depends forever on the necessary and the useful. The plumage of the bird, the mimic plumage of the insect, has a reason for its rich colors in the constitution of the animal. Fitness is so inseparable an accompaniment of beauty, that it has been taken for it. The most perfect form to answer an end, is so far beautiful. In the mind of the artist, could we enter there, we should see the sufficient reason for the last flourish and tendril of his work, just as every tint and spine in the sea-shell preexists in the secreting organs of the fish. We feel, in seeing a noble building, which rhymes well, as we do in hearing a perfect song, that it is spiritually organic, that is, had a necessity in nature, for being, was one of the possible forms in the Divine mind, and is now only discovered and executed by the artist, not arbitrarily composed by him." Emerson, R.W., 1841, Thoughts on Art. *The Dial.*

[38] Emerson's ideas were built on the foundations of the English Romantic movement, where the poetry and literary philosophy of Samuel Taylor Coleridge was a key influence. It was Coleridge who inspired Emerson's ideas on an inner creative generator unique to the individual, which was first presented implicitly through poetry in his collaboration with William Wordsworth, *Lyrical Ballads* (1798). The origins of the innate creative concept cultivated in their work derived from German theories of "vegetable genius" on the organic nature of aesthetic production. This was explored by the post-Kantian idealist including Schelling and Schlegel, but it was further developed into a practical method of literary understanding and criticism for an English readership in Coleridge's work as discussed by Abrams (1953) and Adams (1957).

[39] Shakespeare's poetry was an exemplar of organically structured form, which Coleridge defined in his discussion of the poet: "The form is mechanic, when on any given material we impress a pre-determined form, not necessarily arising out of the properties of the material; as when to a mass of wet clay we give whatever shape we wish it to retain when hardened. The organic form, on the other hand, is innate; it shapes, as it develops itself from within, and the fullness of its development is one and the same with the perfection of its outward form. Such as the life is, such is the form." Coleridge. S.T., 1884, Shakespeare, a Poet Generally. In W.G.T. Shedd (Ed.), *The Complete Works of Samuel Taylor Coleridge* (Vol. IV). New York: Harper and Brothers Publishers.

Following in Wright's footsteps, with Emersonian ideals as a foundation, Portman likewise built an architectural practice that aimed toward organized form. He described this concept as "coordination" – enlarging the scale of architectural agency to take on the structuring (and restructuring) of cities.[40] And also, like Wright, and Sullivan before him,[41] Portman developed a thesis on this concept and an engine for carrying it out. Given an understanding that architects are trained to be synthesizers of a variety of design needs, Portman argued:

> If architects can anticipate the future by understanding growth patterns, if they understand real estate values, if they understand market conditions and market feasibilities, and if they understand the financial climate that makes it right to do something or not to do something, then they will be able to design the city and not just the individual buildings (Portman and Barnett, 1976: 136).

It is this conception of an expanded, self-reliant architectural agency that guided Portman towards a novel conclusion: the architect could generate an independent system for cultural production by learning the art of being an architect-developer too. In this sense, the thesis was simple: that a design perspective could empower entrepreneurial city-making in an innovative, systematic way - and vice versa.

Even more, Portman wrote about this evolving design approach during this early period of his design-development practice to make this model explicit. In his book, he advocated for a more comprehensive agency in the profession as a possible answer to the post-modern condition.

---

[40] Portman and Barnett, 1976: 130-137.
[41] See Adams, 1957.

2.3 The Architect as Developer

In 1976, Portman published a book in collaboration with the architect, urban planner, and scholar Jonathan Barnett[42] to share his vision for *The Architect as Developer*. The book is as much about design as it is about real estate development, but to start with (as the title makes clear) was Portman's thesis that a solution for novel production in buildings and cities involved architects being educated and even more, involved, in real estate development. This vision for practice extended design to address the larger organizational issues of architectural production by inquiring how architecture could operate with greater influence within capitalism. Fifteen years into a personal experiment in this architect-developer role, Portman was sharing lessons learned and asking larger questions on whether the architectural profession as a whole could benefit from the consideration of commercial investment to find new opportunities for constructing urban environments. Portman and Barnett stated that their shared goals were to outline an "integrated design-development process" for building and city design. Portman's work was offered as proof to demonstrate that "designs which improve the quality of urban life can also be sound real estate investments" (1976: 6).

By arguing that the discipline of architecture and the commercial marketplace could mutually engage each other as a larger enterprise, Portman and Barnett were simultaneously critiquing the accelerated market-driven development model in the United

[42] Barnett met Portman in 1964 when he was an editor of *Architectural Record*. Barnett subsequently published the first article describing Portman's design-development practice in the magazine (1966). An architect and urban planner, Barnett was director of urban design for the New York City Planning Department from 1967-71 and a member of the Urban Design Group, which advocated for urban investment in the city through design. Barnett's 1974 book, *Urban Design as Public Policy: Practical Methods for Improving Cities* documented many of the urban projects in New York he participated in, including Portman's Times Square hotel project. In addition to his practice and writings, Barnett also taught in several university programs including at the University of Pennsylvania, where he is an emeritus Professor of Practice in City and Regional Planning.

States. They pointed out that the prosperity and demand on real estate specific to the American capitalist soil, which permitted a habit of “rapid growth and change,” allowed developers to market nearly any design “because any product has been better than none.” The philosophical lineage of the architect-as-developer concept was attributed to the influence of Frank Lloyd Wright foremost, noting how “Wright regarded architecture as a comprehensive discipline that should give shape and direction to all aspects of life” and that this was all part of Wright’s “utopian vision that was national in scale.” The connection through Wright to Ralph Waldo Emerson was emphasized as well, specifically referring to Emerson’s “self-confident optimism” and the “Wrightian belief that the mission of architecture is to make a better world“ (Portman and Barnett, 1976: 21-22), echoing Emerson’s “conversion of the world” proposed as a transcendentalist goal in his 1837 address “The American Scholar."

The architect-developer as conceived by Portman shared in this ambition, aiming to expand design thinking to engage architecture as a commercial product through the “coordination” of an entire “building birth cycle” (1976: 135-136). In practical terms, this meant that designers would get involved in the early stages of land consideration, financing, market studies, and more, so that when early cost estimates were made, they were based on an architectural concept developed considering all of these factors. Portman’s architect-developer hybrid inspired a family of companies to assist in carrying out this vision to offer services ranging from managing properties to purchasing furniture so that these ideals could be developed at all levels of design, considering the interior, the building, and the city. *The Architect as Developer* tells the story of this evolution, emphasizing how Portman learned the development process through a number of advisors, mentors, and collaborators he engaged as partners.

The story is an interesting one to follow in all its details, but even more telling is what was learned through the architect-developer process in terms of coordinating the formal aspects of design. Large-scale architectural projects were emphasized as the necessary arena for growth, to embrace an all-encompassing focus on the total "design of the environment," reflecting an ambition to redefine architecture as a comprehensive design field to bolster the architect's scope of professional influence.[43] While positioning himself against the "mediocrity" of preconceived design ideas, Portman also identified the seeming contradiction in his own work, where the adaptation and repetition of similar forms are clearly present in multiple projects. Considering this, he describes this consistency as one inspired by similar kinds of design problems and the need for an overarching philosophy in design, "a rudder for the boat" that "makes possible a continuing course in a meaningful direction." The repetition, adaptation, and evolution of forms is presented as a purposeful opportunity for experiment, learning, and improvement towards a clarified architectural philosophy.[44]

A more detailed account on this architectural philosophy is presented in the central essay by Portman, 'Architecture as a social art.' In introducing his design ideas and motivations, Portman references Wright's concept of "organic architecture," Louis Kahn's

[43] "It is time for a new definition of architecture and of the architect's role in society. For many years the profession gained its sense of purpose and direction by creating an architecture that would incorporate and express the technology of our time. That battle for modern architecture has now been won. The important issue today is the design of the environment. Architects must redirect their energies toward an environmental architecture, born of human needs and responding to vital physical, social, and economic circumstances. They must work at a larger scale and with more complex problems than they have in the past, but they must not give up the ultimate goal of transmuting their material into works of art." Portman and Barnett, 1976: 60.

[44] "Perhaps it seems a contradiction that you can find design ideas in one or another of my buildings similar to designs I have developed and used elsewhere. Often, the reason for such similarities is that the same kinds of problems are involved. In addition, while I am attempting to develop an appropriate solution to each essential problem, I am also seeking to build up a consistent design philosophy." Portman and Barnett, 1976: 60-61.

notion of a building "wanting to be," and Eero Saarinen's search for the "spirit" of a building to paint a picture of the lineage he aspired to achieve in his own process and principles. The text describes the need for "order and variety" in composition so that attention to human scale and experience, movement, light, color, materials, nature, water, "people watching people," and "shared space" can all be achieved in an organizational system called "the coordinate unit" that is described to conclude the essay (1976: 57-128).

Aiming toward the understanding of growth patterns made explicit in the concept of the coordinate unit at the urban level, Portman experimented with designs at multiple scales that could help build up a design philosophy to complement the architect-developer mindset. He recalls his house[45] as the origin of this formal speculation (Figure 2.1):

> It was in my house that I first began to experiment with the concepts that I had identified as constant elements in the way that people related to their environment. Perhaps I am the only one who can see it, but much of my later work is implicit in that house. It contains the basis for my architectural philosophy: organizing principles that work for a room or a restaurant, a building or a group of buildings (Portman and Barnett, 1976:64).

These organizing principles are the basis for "coordination" – a sense of adaptable formal arrangement that echoes Wright's "'living' structure" (1931) and Emerson's advocacy for

[45] The house was Portman's first design after his visit to South America for the dedication ceremonies at Brasília in 1960 and the completion of the Atlanta Merchandise Mart in Atlanta in the same year: "At this time I had an opportunity to design a house for my growing family; and I concluded that if an architect is ever going to face himself and probe the essence of architecture, there is no better place to start than his own house. There is no excuse other than monetary that one can use. I felt the need to develop a design philosophy in which I could believe, one that would give direction and force to my architecture." Portman and Barnett, 1976:61-62.

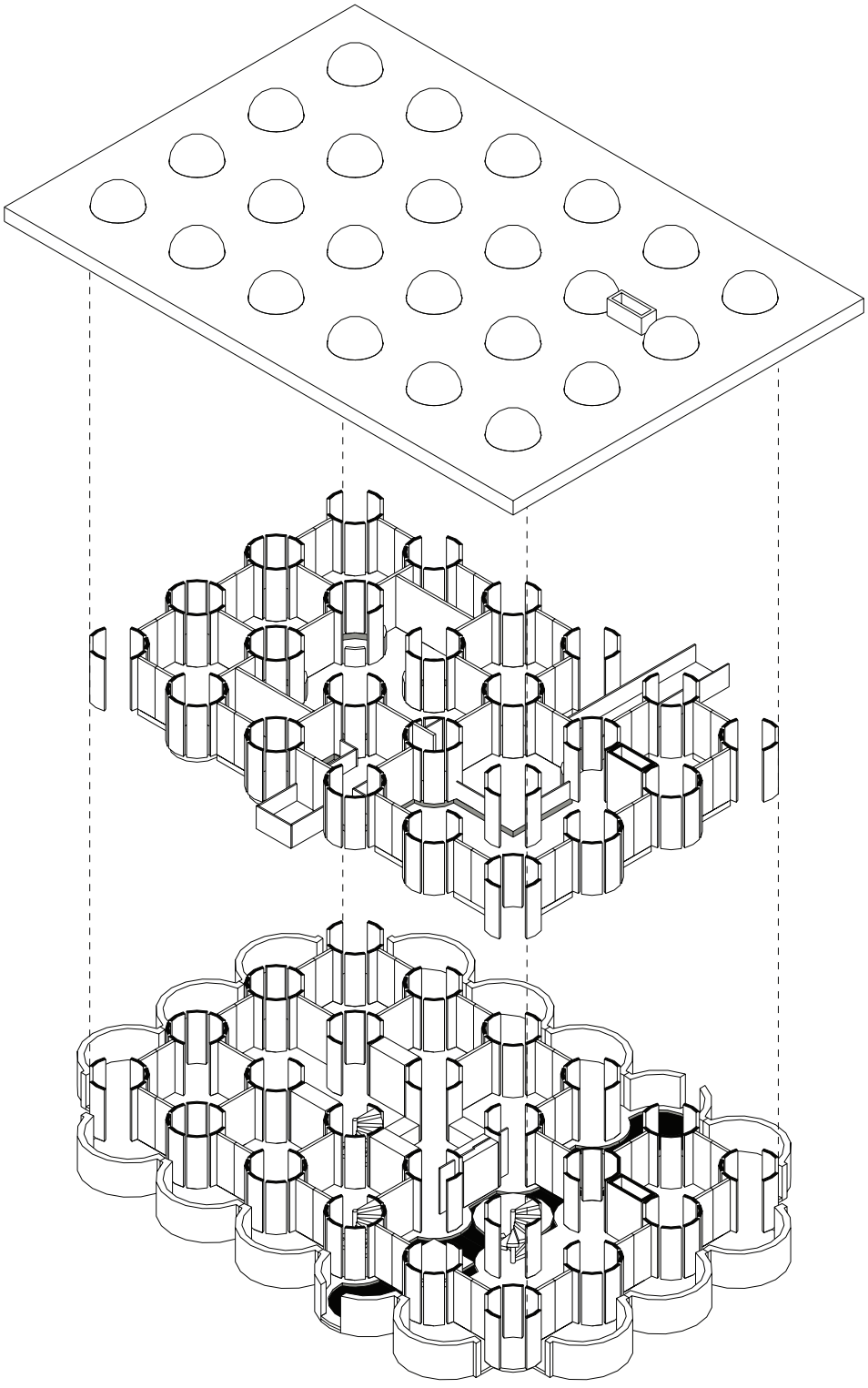


Figure 2.1 Exploded axonometric of Entelechy I.

the study of nature, which Portman emphasized in his humanist approach to the study of architecture in the context of spatial experience. The house that Portman refers to as the resource for his architectural philosophy is his personal residence in Atlanta, completed in 1964 and therefore a precursor to his national and international recognition with the debut of the Atlanta Hyatt Regency in 1967. Originally known simply as Portman's residence, Portman eventually named the house Entelechy I, reiterating it as a formal counterpart to his philosophical pursuits.[46, 47]

Even though Portman has pointed to the house as a precursor to understanding his larger corpus, as well as to the Wrightian and Emersonian motivations behind his concept of coordination, both are largely underexamined in scholarship. Instead, a review of critical perspectives on Portman's work proves plural and full of oppositions, without a thread that can clarify what and how the architecture elicits these views. This ongoing condition appeals to both social and formal interpretations of the architecture – and it can be sorted out in paradoxical terms to emphasize the diversity of critical descriptions to date.

2.4 Portman's Paradox

The polarizing descriptions of Portman's design practice reinforce the challenge of his critical assessment within the architectural profession. Perhaps it is natural to intuit that the architect-developer role is the source of these contentions, but Portman's design work, particularly his large-scale atria and urban designs, are equally cited in the discussion, thus establishing the two main understandings of his contributions to date as:

[46] The house was most likely first called Entelechy I during the design of Entelechy II, Portman's beach residence, which was completed in 1986.
[47] Entelechy comes from the Aristotelian term, ἐντελέχεια or *entelecheia*, a term invented by the philosopher and primarily developed in Aristotle's *Metaphysics*.

a) self-reliant practitioner; and b) megastructure builder. “Portman’s Paradox” is exclusively tied to the opportune relationship between architecture and urbanism particular to Atlanta[48] in Koolhaas’ reading of the work,

> John Portman is a hybrid; he is architect *and* developer, two roles in one. That explains his tremendous power: the combination makes him a myth. It means, theoretically, that every idea he has can be realized, that he can make money with his architecture, and that the roles of architect and developer can forever fuel each other.
>
> In the early seventies, to a power-starved profession, this synthesis seemed revolutionary, like a self-administered Faustian bargain.
>
> But with these identities merged in one person, the traditional opposition between client and architect – two stones that create sparks – disappears. The vision of the architect is realized without opposition, without influence, without inhibition (Koolhaas et al, 1995: 839, 841).[49]
>
> … John Portman is also responsible for single-handedly perfecting a device that spread from Atlanta to the rest of America, and from America to the rest of the world (even Europe): he (re)invented the atrium (Koolhaas et al, 1995: 841).[50]

---

[48] “Atlanta was the test case for an American renaissance, for the rebirth of the American downtown. And you can’t talk about Atlanta’s rebirth without talking about John Portman.” Koolhaas, R. et al, 1995: 839.

[49] “Portman started with one block, made money, and developed the next block, a cycle that then triggered Atlanta’s rebirth. But the new Atlanta was a virgin rebirth: a city of clones.” Ibid: 841.

[50] “Since the Romans, the atrium had been a hole in a house or a building that injects light and air – the outside – into the center; in Portman’s hands it became the opposite: a container of artificiality that allows its occupants to avoid daylight forever – a hermetic interior, sealed against the real.” Ibid: 841.

> … At first the atrium seemed to help rehabilitate and stabilize Atlanta's downtown, but it actually accelerated its demise.
>
> That was Portman's Paradox.
>
> The rediscovery of downtown quickly degenerated into a proliferation of quasi-downtowns that together destroyed the essence of center (Koolhaas et al, 1995: 843).[51]

This shifting tension observed in Portman's work is not exclusive to architecture and urban concerns, nor original to Koolhaas. It is a *continuous* perspective in critical design discourse following interpretations that emphasize the social and the formal implications of the work. An earlier example is found in Peter Cook's thoughts on Portman's stylistic weaknesses and strengths observed during his visit to the Atlanta Hyatt Regency:

> Portman is at his weakest when he has the kind of culture-worry that requires historical and respectable 'quotations' to back up his formal ideas, resulting in one building ranging from OK Japanese split projecting beams to cheesecake Baroque. Or have I set my own trap? Perhaps he is strongest, because once again he is just using things in their natural place, as support for an idea – titillation as just another service.[52]

Cook flips back and forth in his discussion, emphasizing the ambiguity of the conceptual and formal aspects of Portman's design moves, as well as their experiential and perceptual performance. In another view on this tension, Goldberger describes the dual

---

[51] "Atlanta was the launching pad of the distributed downtown; downtown had exploded." Ibid: 841.
[52] Cook, P., 1968. The Hotel is Really a Small City. *Architectural Design, 38(1),* 91.

architect-developer role as an unconventional practice combining design work and profitable real estate development, where Portman “represents neither the establishment nor the counterculture of architecture” (1973). Portman’s work represents an in-between, neither here nor there – a grey area yet to be determined in any sharper resolution.

To focus the review here on an expanded notion of Portman’s paradox, a framework of four conceptual pairs will provide a scaffold for positioning these divergent views to assemble a more comprehensive critical discourse from the varied field of responses. The four pairs are organized so that the first two lean toward the social assessment of the work, while the second two develop a formal discussion. Specifically, the frames are: a) the urbanist as disurbanist, emphasizing design concerns that scale from the individual building to the city; b) the capitalist as socialist, emphasizing design concerns that engage the political, the financial, and the public; c) the humanist as futurist, emphasizing design concerns that characterize the postwar design context of the 1960s-1980s; and d) the pragmatist as formalist, emphasizing design concerns in terms of a customized, individual architectural output.

2.5 The Urbanist as Disurbanist

In Portman’s hands the atrium was reworked as a monumental design gesture read at the scale of urban intervention. Rice has described this phenomenon as an “interior urbanism” particular to American downtowns of the late 1960s and 1970s. Seen as a paradigmatic example of the time, the “atrium effect” is displayed in Portman’s architecture during this period, where the relationship between architecture, interior design, and commercial real estate development seemed to merge with the emerging field of urban design as Rice describes:

> The atrium, and its attendant spaces such as pedestrian links and concourses (above and below the street), emerged as a distinct way of conceiving and constructing the city. The atrium enveloped, encompassing the city's exteriority within architecture's spatial and organizational repertoire. This repertoire, itself transforming along with the emergence of the atrium – the moniker 'megastructure' was routinely applied to such projects – combined with an ordered and strategic process of intervening in and thus remaking the city. Emerging in this combination, interior urbanism galvanized action as well as critical debate, and arrayed architects, city planners, politicians, financiers, theorists and critics around downtown as the urban problem of the period (Rice, 2016:4).

The atrium as a conceptual and constructive device thus blurred the boundaries between interiority and exteriority so that the interior was urbanized within a system of relationships that together reformulated the city to address the urban challenges of the period.

In the 1970s, Ada Louise Huxtable described this condition as "Instant City," citing Downtown Atlanta as "the new American city in microcosm," constructed in only a decade.[53] Portman is positioned as the key figure behind this rapid renewal, delivering a significant contribution in American urban culture that was not only tied to the superficial "flying saucer cocktail lounges" of his hotels, but more importantly to the educational task he assumed in his dual architect-developer role, where "he is teaching developers – by being one – how to give the city an essential connective tissue of use and amenity, to

[53] "This is Instant City. Downtown Atlanta has been built in the last 10 years. What you see in the mile-and-a-half of Atlanta's business heart is what you get: a concentration of totally new office towers, hotels, shopping facilities, landscaped streets, plazas and parks that are a product of the sixties and early seventies – an incredibly unified achievement in an unbelievably short time, when other cities were struggling with piecemeal renewal" (Huxtable, 1974).

make it workable and attractive in function and design." Huxtable described this as "the missing element in both speculative building and urban renewal" (1974).

Zooming in from a broader view of urbanism in Portman's work to focus on the atrium, the space of the individual building was equally seen as a microcosm - a city within the city. Peter Cook, whose experiments on the city with Archigram pursued a futuristic urbanity that was likewise interested in megastructure,[54,55] saw the atrium as a city unto itself. In an article titled 'The Hotel is Really a Small City,' he described the Atlanta Hyatt Regency as a "real use of the conditioned environment," where "a building really has a middle" (1968), suggesting how the space was fundamentally different in its scale, experience, organization, and mechanics. Paul Goldberger related the space of the atrium to the intersection of the urban/interior (or public/private) as well, describing it as a space containing "all the elements of a town square within the room." He further described this as a condition that "creates a kind of tension which is probably not unnoticed by the hotel's visitors; in fact, it is that ambiguousness – that sense of being at once both inside and outside – that gives the atrium much of its value as an architectural experience" (1974).

The replication and proliferation of elements naturally considered exterior within an artificial interior context reinforced this ambiguity between the interior and the urban. As a hermetically sealed world, the atrium is also the initial setting for a discussion on the utopian ideals of Portman's urbanism, seen in its ties to nature and growth. Nature is

---

[54] Reyner Banham's *Megastructure: Urban Future of the Recent Past* (1976) argued that the large-scale postwar projects, wherein architects (including Archigram, Team 10, Superstudio, the Metabolists, etc.) engaged monumental designs proposed at scales that merged architecture and urbanism, were "the hinge of a crisis in architectural thinking" characteristic of the end of Modern architecture.

[55] Jonathan Barnett, Portman's co-author on *The Architect as Developer* (1976), offers a concise definition of megastructure: "the city as a building" in *The Elusive City: Five Centuries of Design, Ambition, and Miscalculation* (1986).

incorporated literally in the atria, which Reinhold Martin contextualizes within the "ruins of the city-machine" where "the rise of the Portmanesque atrium is therefore more like the sprouting of a new *nature* from amidst the empty shells of warehouses, factories, and other such leftover equipment from the first machine age." Martin elaborates on this growth as a "new regime," responding to the decline of modernism with the characteristic greenery filling Portman's atria: "the regime of the potted plant" (2009).[56,57]

The plantings and notions of growth and expansion in this urbanism are initiated in the interior of the atrium, but from there extend to a city scale that relates Portman's work to other utopian projects that aimed to radically reinterpret the urban to accommodate vital growth and distribution. At times interpreted as anti-urban in their alternative mindset – and in that way paradoxical too - the movements defined by the Japanese Metabolists and the Soviet Disurbanists offer intriguing comparisons to Portman's urbanism. The Japanese Metabolists aimed for a structural growth that would construct a living city. In their 1960 manifesto, they declared:

> Metabolism is the name of the group, in which each member proposes future designs of our coming world through his concrete designs and illustrations. We regard human society as a vital process – a continuous development from atom to nebula. The reason why we use such a biological word, metabolism, is that we believe design and technology should be a denotation of human society. We are

[56] "In other words, the whole point of opening up these large, complex and expensive voids on the interior of massive downtown developments like Peachtree Center was not so much to negate or to refuse the city but to reproduce it, as a distorted reflection, a kind of inside-out mirror image of the urban public realm or civic center. Think of Rockefeller Center, turned inside out." Martin, 2009.
[57] Michael Sorkin similarly described the skyscraper-atrium in Portman's work as "the skyscraper outside in" with hotel courts "inevitably swaddled in enough dangling greenery to refoliate the Amazon Basin." He positions the "most refined precedent" of the skyscraper-atrium as Kevin Roche's Ford Foundation Building, "a seminal inversion of modernism's classic vision: the park's now in the tower." Sorkin, 1994:272.

> not going to accept metabolism as a natural historical process, but try to encourage active metabolic development of our society through our proposals (Kikutake et al., 1960).

Lin has argued that the work of the Metabolist movement represents three distinctive paradigms of urbanism: megastructure, group form, and ruins – all understood in terms of urban intervention as an ongoing process of change (2011). Mohsen Mostafavi claims that Portman's work achieves the Metabolists' goal at the urban scale, well beyond what they were able to accomplish in individual building projects because he "built on the scale of the city, both architecture and more than architecture." Mostafavi suggests that from this perspective Portman's work "constitutes a kind of new understanding of 'urban,'" one perhaps unachievable without his hybrid practice of design and development (Medina, 2017).[58] In this sense, the Metabolist notion of process in urbanism – one explicitly described in Fumihiko Maki's advocation for sequential development in his concept of group form (1964) - bears the closest resemblance to Portman's interpretation of a design process at the intersection of development, architecture, and urbanism.

This particular urbanism, characterized by design-development and the atrium as a chief product, proliferated globally and was described by Koolhaas in its relation to Soviet Disurbanism.[59] Building on this connection, Portman represents less the constructive urbanist and more the cataclysmic "disurbanist to the world" (1995), a caricature which is

---

[58] …"most of the Metabolists' work ultimately remained at the level of the individual buildings, which expressed a certain structure and a certain idea of growth. The exceptions to this – Kenzo Tange's Tokyo Bay project, for example – were never realized, and so the relationship between architecture and a greater pull as a set of relations was missing. But I think John Portman did this." Mostafavi quoted in Medina, 2017.

[59] Koolhaas' footnote reads, "*Of course, the word *urbanism* – which somehow suggests a minimum of steering – does not apply. For now, we could adopt the term *disurbanism* which, in the twenties, described a branch of constructivist urban theory aimed at dissolving the city." Koolhaas et al, 1995: 836.

perhaps far more insightful than it has been given credit for.

Soviet disurbanism promoted decentralized planning to equate socialist design with the socialist revolution, yet the disurbanist efforts were largely misunderstood. This misunderstanding is captured in a letter written by Moisei Ginzburg to Le Corbusier in defense of his disurbanist scheme for the 1930 competition for Moscow's Green City, where he explained:

> We are removing from the city nothing less than the city itself, its entire system of supply and culture. In other words, we are creating a whole new organism … You write that the peasant does not love flowers and does not hear the song of the skylark…
>
> But we want our peasant to listen to the skylark … And all this will be possible not by smoothing out the contradictions with which the modern capitalist system is riddled, but by creating new forms of human settlement more worthy of the future.[60]

Portman's desire to generate a whole new organism at the urban scale is where his disurban tendencies come into play. In its uninhibited sense of urbanism as an ongoing process, Portman's architecture is distinctively politicized in its financial and social implications.

2.6 The Capitalist as Socialist

Portman's (dis)urbanism foregrounds how his designs relate to political and economic systems, projecting an attitude towards the city that embraces capitalism

[60] Translated in Kopp,1970: 254.

through socialist spatial concepts to reconfigure notions of public, private, and power. These decontextualized spaces are equally contextualized as timely and emblematic reflections of reality in the postmodern, global metropolis. This relationship to socialism has come forward as a means to deal with Portman's pragmatic, yet unedited, role as architect-developer to steer a new course in architecture, land-use, and development with maximum control not unlike the Soviet Constructivists after the Revolution – a power that for Portman was realized in the capitalist challenges of a postwar, 1960s Atlanta that equally sought new urban constructs as catalysts to counteract the erosion of downtown.

Spatially, the argument revolves primarily around the atrium as a collective, social organizer. Portman's hotel designs are described as operative social condensers, as in the prototypes birthed for a socialist, post-Revolution society:

> In the Atlanta Hyatt Regency, which was the first of the hotels to be developed, a rectangular solid made up of rooms and corridors is inflated to monumental proportions by the atrium, which is a kind of world unto itself populated by shoppers, hotel guests, and potted plants. Such figures – atriums with glass elevators, shoppers, hotel guests, and potted plants – will follow Portman throughout his career. But interestingly enough, the first Portman-designed atrium was not for a business hotel but for the Antoine Graves Houses, a publicly subsidized housing complex for elderly residents. Already there, the idea was to organize the social life of the complex around its twin enclosed courtyards, or atriums, at the perimeter of which ran the main circulation to the apartments. This is how the classic Portmanesque hotel atrium works – as a sort of social condenser, a privatized public realm that, nevertheless, is dedicated to social interaction, albeit of a highly circumscribed variety (Martin, 2009).

Martin goes on to argue that Portman's work is "symptomatic, not exemplary … its distance from the architectural canon also offers us a unique perspective on the way in which Architecture – with a capital A – functions in the contemporary arena." This function is directly related to capital and power, which "begins to look friendly, warm, and natural" in the atrium (2009; 2007).

This view is an extension of the argument that Portman's atria are representative microcosms of the global realities of money and meaning from the late 1960s to the mid 1980s. In particular, Portman's Bonaventure Hotel in Los Angeles is characterized by Jameson as the manifestation of a capitalist, postmodern society, a self-referential 'hyperspace.' He describes the hotel as the spatial analog to global capital in its separation from local surroundings and disorienting configuration of a privatized, interior reality. Jameson contended that the hotel aimed to be "equivalent" to the city itself – and the relationship between architecture and international financial markets made this attitude representative of the postmodern condition (1991). Building on this position, Pope describes Portman's atrium as an "urban landscape" that attempts to overcome the city "but can ultimately only simulate" its realities (1996: 126). Rice picks up on this too, but shifts the argument, describing Portman's work at the urban scale (and particularly the atria) as a "geometric encoding" that "provided the calculus for financial evaluation," making it conducive to addressing the "difficult" realities of the architectural discipline and large-scale commercial production at a global scale (2016: xi; 41).

Portman's response to the capitalist power dynamic between architectural design and commercial development was to embrace both. This caused him to be called before the American Institute of Architects' board of directors in 1968 to discuss whether this was

a conflict of interest.[61] Ultimately, it was determined an acceptable mode of practice that has attracted many practitioners since. Today this controversial hybridization in the discipline is reconsidered as an act that empowers the role of the architect:

> As a profession we have not been able to investigate in sufficient depth our relationship with development. Because of that, much of what we do too easily falls within the realm of the service sector. I'm not suggesting for a moment that all architects should become developers. But I do think that there needs to be some room and discussion about the way architects can become more empowered in shaping the built environment. That is something John has been able to do precisely through development … Of course, there may be other ways to think about empowerment. This I think has consequences in terms of our fees, salaries, and position in society. How much value are we willing to give architecture in our society? How do we change the perception of our discipline at this level? These things are interconnected … How do we think through an expanded role for the architect today? John Portman can help inspire that conversation.[62]

The transition from architecture as a service profession to architecture as an instrument of systematic change was particular to the political and economic climate, blending socialization and commercialization by design. Still, Portman's commercial architecture aimed to stand out formally, making him a "foreground architect to the end," one who sought to humanize modernism through his interpretation of space – even in "popular," development-driven buildings (Goldberger, 2009: 20).

---

[61] Kennedy, S., 1988. Architects Now Doubling as Developers. *The New York Times*. February 7, 1988, Section 8, Page 1.
[62] Mostafavi quoted in Medina, 2017.

2.7 The Humanist as Futurist

As part of the Postmodern tradition by chronological default, the visionary aspects of Portman's forms are predominantly read as a function of the larger, postwar disciplinary context in architecture, interior design, and urban design. His designs straddle past and future in their forms, bringing together humanistic and futuristic design ideals. The attraction that Portman's designs elucidate reinforce Jameson's "cultural logic of late capitalism" and echo the general understanding of postmodernism as a style of "historical citation" or "populist play" (Martin, 2009). In this context, the consuming environments created in Portman's designs have been related to caricature as discussed in an interview between Peter Eisenman (PE) and John Portman (JP) in 1983:

> PE: One could say that most architects today have lost their nerve and become eclectics. In other words, the people who are picking and choosing from history do not concern themselves with originality or taking risks. The visionary, the dreamer, seems to be disappearing.
>
> JP: I agree.
>
> PE: I would like to reintroduce the idea of caricature – you used the term earlier. Walt Disney World is a city, with all the technology of a city, yet it is a caricature of a city. Jonathan Barnett[63] has said that your interiors are like amusement parks. The same people you are criticizing for caricaturing history would criticize you for creating things that are caricatures of human experience – in the same way Walt Disney World is a caricature of the future.

[63] Portman's co-author on the 1976 book, *The Architect as Developer*.

JP: I am not dealing with caricature. I am dealing with the question of how to create spaces that have a positive effect on people. I was very influenced by the Tivoli Gardens. They really are the grandfather of Disneyland. It is not the same, of course, but I recognized at Tivoli, for instance, the positive effect an environment can have on the emotions. I have been quoted as saying that I create Disneylands for adults. I did not mean that I am designing Disneylands per se, but that I am trying to understand those ingredients – the magic about those environments – that give people pleasure. In this day and age, when there is so much stress, to give pleasure and happiness is terribly important. If we can create that sort of environment in our cities, then architecture should not do less.

PE: Are you saying that you are not trading in instant gratification? Do you really feel that the buildings you build today will give the same pleasure fifty years from now?

JP: Yes. What I am doing is building on the human, innate responses to environmental conditions. There are all sorts of variables from one project to the next, but the human experience is a constant. My observations about people's reactions to the constructed environment define where I stand in architecture. I don't know what I'm going to do next, but I do know that no matter what architectural form may evolve, what I do next will incorporate this philosophy.[64]

Portman's response to the failure of modernism aimed to humanize architecture through spatial systems and corresponding effects that appealed to the senses. The constants driving this approach were based in human response to conditions of their surrounding

[64] Eisenman, P., 1983. Interview: John Portman and Peter Eisenman. *Skyline*, January 12.

environments, which Portman maintained as directly observable.

The designs coming out of this philosophy were sometimes described with historical referents, while alternatively considered forward-looking. Portman's "postmodern" response has been understood as a reinterpretation of the baroque in its theatrical attraction to popular culture. Michael Sorkin relates Portman's spatial effects in the atrium to a drug-induced Bernini,[65] "Bernini on an acid trip" (1991: 272). Jennifer Bonner develops this connection by describing the 1985 Atlanta Marriott Marquis hotel as a "glamorous view of Portman's baroque" (2017: 349). A less glamorous review of Portman's Marriott Marquis at Times Square in Manhattan, completed in the same year as the Atlanta Marquis, argued that his work was out of sync with the times and perhaps too dependent on the modernist tradition: "it is to architecture as the Edsel was to the automobile — awkward, gangling, and out of touch" (Goldberger, 1985). Additional characterizations have related Portman's architectural forms backwards to evocative echoes of the Minoan Palace and the Hypostyle Hall (Craig, 1989), and even forwards to an imaginative dystopian future, which is how the movie industry has interpreted the theatrical forms since their completion (Hays and Porter, 2017).[66]

Reinhold Martin sees Portman's monumental forms as indicative that he was working on the same postmodern problem of "collective meaning" in architecture that Louis Kahn chased after. They both pursued a hollow architecture, but in different ways. Kahn's "monumental hollowness" was based on the historical, "nothing but empty form, a

[65] Gian Lorenzo Bernini was a 17th century Italian sculptor and architect, whose work was known for its eccentric baroque style.
[66] A running list of films, tv series, commercials, music videos, and video games that utilize Portman's forms in their scenery is available at https://www.portmanarchives.com/film-locations

ruin before it was built," while Portman addressed "de-humanized-downtowns" with the atrium, "an object with special powers, designed magically to bring these ghost towns back to life." Martin argues that both Kahn and Portman pursued fetishes in their forms, "an intensified form of sensory-spatial experience and symbolic sociability" which is what relates their architecture in the postwar period. From this point of view, the Utopian ideals of Portman's atria – in their comfort, domestication, and harmony - project a postmodern "hallucination" (Martin, 2009).

However, more recently (and posthumously), an opposite view has come forward. Portman's work continues to be reassessed in its "radically optimistic vision of the future that resonates deeply in a present time of seemingly unprecedented uncertainty" (Denny, 2018). Perhaps this is due to the very comfort that Martin describes, but nonetheless the "wildly original works of this hybrid architect-developer stand in stark contrast to the often banal and sometimes-destructive creations of unfettered real estate development that are the tradition of modern city-building in the U.S." (Denny, 2018). Whether humanist fetish, futurist vision, or simply an alternative to stereotypical practices in real estate development, Portman's work continues to project an interest in resolving the issues of money and meaning in architecture. This is achieved through forms that are simultaneously concerned with pleasure and profit.

2.8 The Pragmatist as Formalist

Portman's forms have been described as developer-driven in their efficiency and formally driven in their exuberance, in both cases defining a signature logic or architectural language. To this end, his work has been consistently approached in terms of "Portmanian" devices, vocabularies, and tropes. Paul Goldberger distinguished Portman's

design language not as one of applied ornamentation, but of spatial invention:

> Portman uses not decoration but devices – primarily great space, bold geometric forms and movement – which, while not subtle, are sophisticated enough to create a feeling of interest and excitement, and the sense that the building is an unusual experience, even an ennobling one. Portman's buildings have the remarkable ability to cause people to examine their own notions of what architecture is (1974).

These devices are discursive and immediately appreciated by the public, giving the works their popular appeal. Thirty-five years later, Goldberger continues to build on the notion of devices in Portman's architecture, "Portman's shapes, his spaces, his mixes of solids and voids, colors and textures, swooping grandeur and conscious intimacy – these are all devices intended to make a modernism that is readable and inviting" (2009: 20). Herbert Muschamp described the overall effect of this as "architecture at happy hour," reinforcing the hospitable and celebratory environments created through these moves – a spatial exercise in delight despite their perceived urban exclusion (1992).[67]

Morris Lapidus describes an "unmistakably Portmanian" language in the work. The glass observation elevators were the first signature element of this architectural language, which also includes atriums and circular buildings. Lapidus notes that, "this is not a criticism … architects throughout the ages are recognized by their own specific vocabulary" (1978). This sense of vocabulary has recently been opened up in the critical

[67] The notion of urban exclusion was not discussed in earlier critical reviews of Portman's work. Ada Louis Huxtable described Portman's style in relation to Atlanta: "Atlanta has its own image. It is not made up of the dropped-in, anonymous, interchangeable parts that characterize so many other cities. The Atlanta style is recognizable, and it has been sparked by one man, John Portman, the 49-year-old architect, who not only started the boom but set the design standards. This style combines a kind of Buck Rogers flash with an extremely astute and experienced sense of urban design" (1974).

interpretations of Preston Scott Cohen (2017) and Jennifer Bonner (2017) at the Harvard University Graduate School of Design (GSD).

In a design studio focused on 'Portmanian Architecture' at the GSD, Cohen aimed to invert tropes of Portmanian architecture towards a language for contemporary urban design that could address the paradox of Portman's forms in their interior success and urban challenges. To initiate the project, Cohen introduced thirteen tropes of Portmanian architecture, each describing a spatial element or architectural concept distinctive to Portman's forms. These include: a) The Glass Elevator; b) The Exposed Elevator Shaft; c) The Articulated Elevator Shaft; d) The Transverse Spatial Sequence; e) Hotel Corridors Open for Viewing from Afar; f) The Articulated Railing; g) The Blurring of Automobile and Pedestrian Thresholds; h) The Suppressed Entry; i) The Isolated Architectural Figure; j) The Revolving Restaurant; k) The Discrete Articulated Façade; l) The Aggregation of Vertical Masses; and m) The Reductive Cylindrical Hotel Tower (2017: 279-309). These thirteen tropes include the three vocabulary elements that Lapidus described, the glass elevator (a), the isolated architectural figure of the atrium (i), and the circular building (m), and expand the notion of language to include a series of spatial elements and relations.

Lapidus' three vocabulary elements appear again in Jennifer Bonner's description of Portman's language as one of "architectural pizzazz." She claims nine persuasions in his work to develop this conception, which again include the glass elevator (f), the atrium (b), and the circular building (e). Specifically, Portman's pizzazz is characterized by: a) Overturning Assumptions about the Ordinary; b) Amplifying the Interior; c) An Architecture that Rotates; d) Overstating the Corner; e) The Faceted Condition of the Extruded Cylinder Type; f) The Use of Glass Elevators; g) Making Additions on top of Parking Garages; h) Tivoli Lighting; and i) Reimagining the Baroque (2017: 343-349). A few of these also recall

Cohen's tropes, for example c) An Architecture that Rotates is similar to Cohen's j) the Revolving Restaurant, indicating commonalities shared in both interpretations of the vocabulary.

More formally and simply, Rice describes Portman's interior urbanism as one of "hollow forms," where "consistency of geometry" is the primary indicator of continuity. In this interpretation, these geometries are described as provoking an "understanding of architecture's instrumentality as the basis for a spatial and organizational analysis," one particularly tied to the pragmatics of the architecture in its relation to commercial development (2016: 119). These geometries are, in fact, repetitive indicating a series of possible influences in design more broadly considered. Even more, this critical view highlights the unresolved tension between the pragmatist and the formalist, suggesting the need for a different approach to Portman's architecture, one that can make sense of this landscape.

2.9 Discussion

The conflict in critical interpretations of Portman's work, whether considered socially or formally, is persistent. This ongoing, ambiguous response in the architectural community brings forward multiple characterizations, including: a) the urbanist as disurbanist; b) the capitalist as socialist; c) the humanist as futurist; and d) the pragmatist as formalist. The urban, disurban, capitalist, and socialist views on the work evoke opposing tensions in terms of social implications and broader urban effects. While assessments of humanist, futurist, pragmatist, and formalist perspectives likewise foreground oppositions in the perception of Portman's formal output in the architecture and designed environments of his corpus.

Two additional areas of impact, where the geometric aspects of Portman's designs have motivated other influences hint at another perception that may be more productive, telling, and paradigmatic. These influences reference Portman's contributions in relation to computation, and more specifically in software design and parametric design. Alan Cooper, a software designer known for developing Visual BASIC (which ushered in the field of interaction design), cites Portman's architectural designs as having an influence on his work designing software applications (Steenson, 2017: 58).[68] With respect to parametric design, Mohsen Mostafavi has suggested that Portman's architecture "deals with repetition, but at the same time, it has the capacity to be radically innovative … Whatever it is, the projects offer a multiplicity of readings." He describes these readings in terms of how architectural photographers have framed the buildings in various ways and then continues, "These buildings are 40, 50 years old, but if you think about them in terms of form, they still seem quite unusual. Some of the architectural moves are closer to what we might now call parametricism" (Medina, 2017).

These connections to computation evoke the algorithmic, rule-based aspects of Portman's forms that have yet to be readily pursued in design research and perhaps offer insights as to why this particular formal language has continued to generate paradoxical and overlapping views. To reinforce this perspective in a more precise way, Portman's reflection describing Entelechy I as the generator of his architectural principles and ideas for spatial organization at various scales (Portman and Barnett, 1976; Portman, 1997) provides a clue as to how a novel theory on his forms might be constructed.

[68] Steenson notes that most software designers are only familiar with one architect, Christopher Alexander, whose interest in patterns in design have been inspirational for the "architecture" of computer.

2.10 Summary

A narrative framing the context of Portman's practice was elaborated in this chapter. The question of the post-modern in American architecture intersects precisely with the beginning of Portman's architectural practice. A reminder of this particular moment allows for an interpretation of the motivations behind the work, which point to the ideals of Frank Lloyd Wright and Ralph Waldo Emerson as a basis for Portman's concept of coordination. The subsequent design philosophy developed out of this relation is brought forward in a discussion of *The Architect as Developer* (Portman and Barnett, 1976), where Entelechy I is established as the key figure of Portman's corpus. Nonetheless, a critical review on Portman's work to date establishes ongoing characterizations that do not engage the possibility of the house as generator, nor the algorithmic potential of the work. To unpack this potential in further detail, Entelechy I and a broader corpus of Portman's designs are presented and analyzed in the chapter that follows to foreground the concept of coordination as a basis for interpreting Portman's designs in an algorithmic way.

CHAPTER 3. COORDINATING FORM

3.1 Introduction

Beginning with Entelechy I (Portman House), a selected corpus of Portman's designs will be presented in this chapter as an introduction to his architecture. After the house, designs at three additional scales will be presented, including interior design, hotel design, and urban design. All of these designs appeared in *The Architect as Developer* (Portman and Barnett, 1976)[69], suggesting their importance to Portman's thesis developed in a series of interiors, buildings, and urban plans. A final design not included in the book, Portman's 1986 beach residence, Entelechy II, provides a second residential design to complete the primary corpus curated for the research.

3.2 Portman House (Entelechy I)

Seen as a means to "probe the essence of architecture," the design of Entelechy I was made possible by the completion of the 1961 Atlanta Merchandise Mart.[70] In fact, the opportunities opened up by the Mart's success and Portman's adoption of the architect-developer model sparked new thinking on how architecture could have systematic impact

[69] Portman's co-author Jonathan Barnett is an emeritus Professor of Practice in City and Regional Planning, and former director of the Urban Design Program, at the University of Pennsylvania. Barnett met Portman in 1964 when he was an editor of *Architectural Record*. Barnett subsequently published the first article describing Portman's design-development practice in the magazine (1966). An architect and urban planner, Barnett was director of urban design for the New York City Planning Department from 1967-71 and a member of the Urban Design Group, which advocated for urban investment in the city through design. Barnett's 1974 book, *Urban Design as Public Policy: Practical Methods for Improving Cities* documented many of the urban projects in New York he participated in, including Portman's Times Square hotel project.

[70] "… I concluded that if an architect is ever going to face himself and probe the essence of architecture, there is no better place to start than his own house. There is no excuse other than monetary that one can use. I felt the need to develop a design philosophy in which I could believe, one that would give direction and force to my architecture." Portman and Barnett, 1976: 62.

in Atlanta and beyond, ideas that Portman was eager to test further. Motivated by this interest, Portman attended the dedication of Brasília in 1960 while construction of the Mart was underway. He describes the visit as a reconnaissance tour, where he hoped to find answers to contemporary architectural and urban questions resolved in “a new city completely designed by architects” that could inspire his own work in Atlanta. However, the actual experience proved disappointing, resulting in more questions than answers. Specifically, concerns about the singular, overwhelming scale and predictability of the environment prompted Portman to describe Brasília as “inhuman.” In his narration, he describes how this letdown ultimately shifted his focus to the failure of architecture at the scale of the city and the disciplinary problem of how to restructure design across scales to address human experience (Portman and Barnett, 1976: 61).[71]

Entelechy I (Figure 3.1) was the first project that allowed Portman to pursue this challenge directly. Portman describes the ambition of the moment in how he came back from Brazil resolved to “improve … as an architect in two ways: first, to learn how to design at the scale of the city; and, second, to find ways of making buildings more responsive to human values” (Portman and Barnett, 1976: 61). Working as his own client, designing the house allowed for the discovery of new organizational principles to address the need for a revised architectural design approach, while also generating a theory to back it up. Originally designed for Portman and his family of eight, the concept for the house was a lively pavilion inspired by the coincident order and variety of nature.

[71] “This trip to Brasília made me realize that many of the design concepts that had come to be accepted by the architectural profession did not work very well at the scale of an entire city. Older cities, no matter how badly their designs had evolved, were still better at providing for human needs than Brasília, whatever the virtues of the architecture. I came to the conclusion that what we needed to do in the United States was to restructure our existing cities, not build new ones.” Portman and Barnett, 1976: 61.

Figure 3.1 Entelechy I: exterior view. Image © 1965 Alexandre Georges, The Entelechy I Collection, courtesy The Portman Archives.

Portman designed Entelechy I in 1964 and lived there for the duration of his life. At the time, Portman was primarily known, as an article in *Interiors* introduced him, as a "builder and owner of giant commercial structures," but spatial invention was not the highlight of his achievements. The same article tracked the house as milestone: "In his home it is clear that he has until now repressed a compelling drive to explore new ideas about space" (Gueft, 1965). Multiple publications, including *Architectural Record* (1965) and *Architectural Digest* (1970), echoed this sentiment upon completion of the house in the 1960s and again in a set of later articles in *Interior Design* (1982) and *Southern Homes* (1989) inspired by 1980s renovations. These features focused on the uniqueness of the

design and its flexible spatial expression, aspects that mark a shift in Portman's work from this moment onwards.

The house is built on a 12-acre lot located on the north side of Atlanta that was selected both for its privacy and its provision of elevated views to the city's skyline (Figure 3.2). Set back and hidden from the street, the siting of the residence allows for a processional arrival. Upon entering the property, the driveway choreographs an approach on axis with the main entry to the house that leads to a circular loop and lawn that further directs arrival toward the house.

The circular drive splits into an inner and outer loop to coordinate two courses of arrival: a front- public entry for guests ascending along the inner circle and a "back-door" private entrance descending along the outer loop for the family (Figure 3.3(a)). These front and "back" entrances are uniquely positioned directly on top of each other, an arrangement that takes advantage of the sloping site. The main entry on the upper floor reiterates an initial impression of a low, long house as guests arrive (Figure 3.6). To reach the front door from the driveway, steps lead to a circular platform with a radiating balustrade that also functions as a covered carport for the "back-door" below (Figure 3.3(b)).

The house is designed around a rhythm of circular architectonic elements (Figure 3.4). These elements, characterized as columns that are hollowed out or as columns that are fragmented or exploded, what Portman calls "hollow columns" or "exploded columns" (Portman and Barnett, 1976), carry the full load of the structure and are each capped by an individual skylight penetrating the platform roof. Around the perimeter, these curved cypress-clad columns are expressed for the full 17-foot height of the two-story steel and

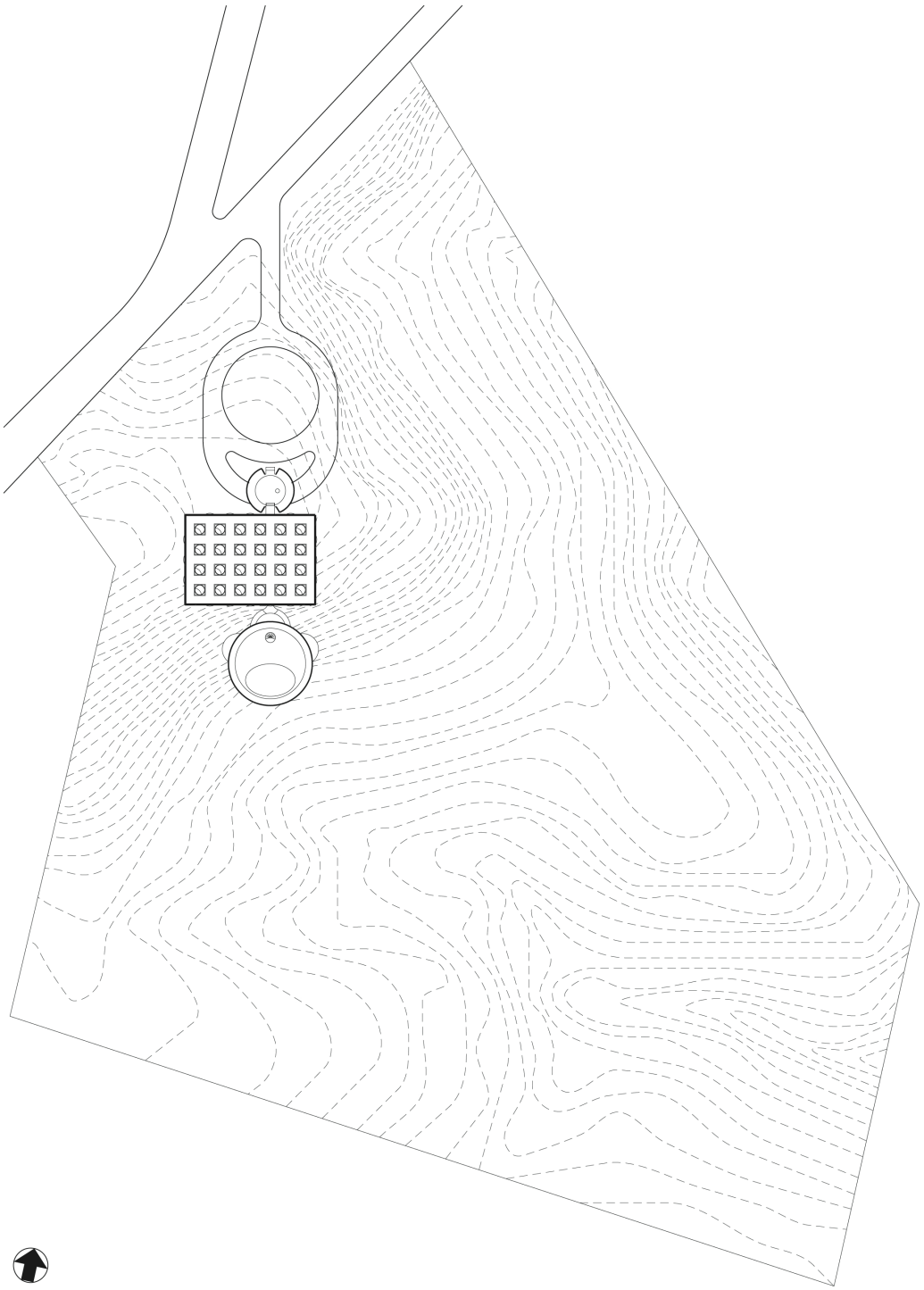


Figure 3.2 Overall Site Plan. The house is sited on the northern part of the lot to take advantage of an elevation that offers views to Atlanta's skyline to the south. From north to south, the plan shows the entry drive, front lawn, entry bridge and carport, main house, and back pavilion with rooftop swimming pool.

(a)

(b)

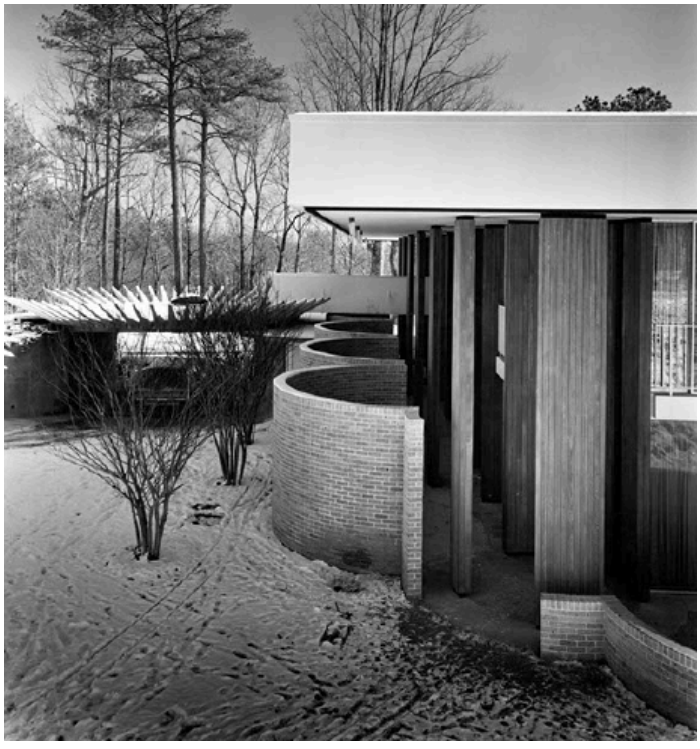
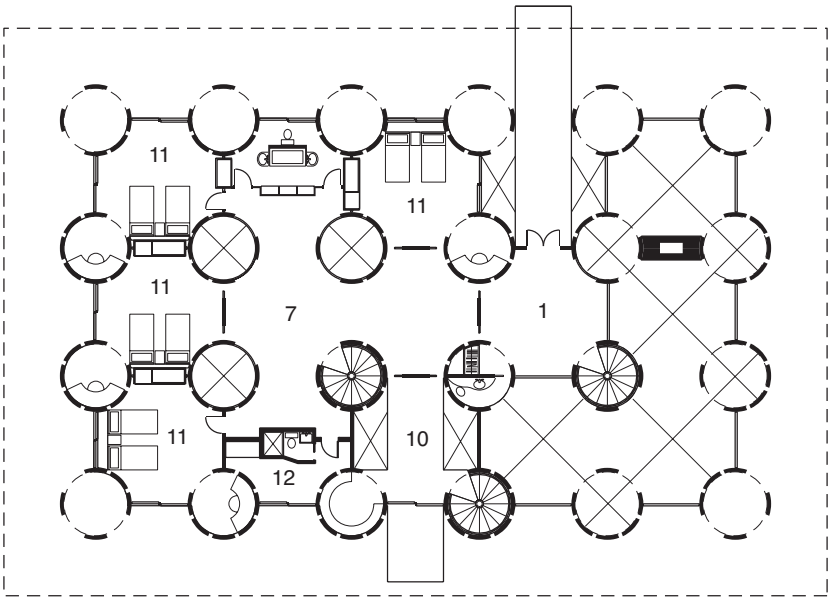
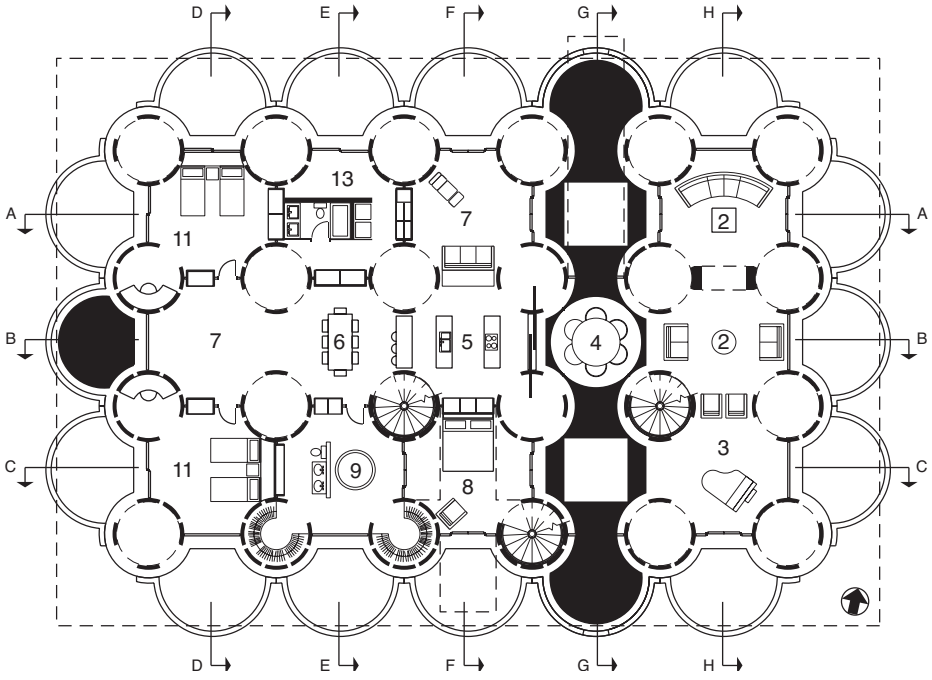


Figure 3.3 Arrival sequence: (a) Exterior view approaching the house from the driveway. Image © 1964 Clyde May, The Entelechy I Collection, courtesy The Portman Archives; (b) Exterior view from the west showing the entry bridge and carport beneath. Image © 1965 Alexandre Georges, The Entelechy I Collection, courtesy The Portman Archives.



(a)



(b)

Figure 3.4 Floor Plans of Entelechy I: (a) upper floor (main entry level) plan; (b) lower floor plan. Legend: 1. Entry foyer, 2. Living room, 3. Music room, 4. Dining room, 5. Kitchen, 6. Family dining room, 7. Family/play room, 8. Master bedroom, 9. Master bathroom, 10. Master study, 11. Bedroom, 12. Staff bedroom, 13. Laundry/utility area. (Drawing by author).

concrete structure conveying a temple-like continuity that is carried on in the interior to define a complete grid of twenty-four figural columns. This relentless stability allows modular spatial divisions and penetrating volumes throughout the house to be woven together adding layers of complexity to the space. The resulting combination creates a pliable spatial structure flexible for the diverse needs of a dynamic family life.

The actual exterior enclosure is defined by a combination of the hollow columns and immaterial glass partitions weaving between them at their centerlines, blurring the distinction between interior and exterior. In fact, it is the canopy roof rather than the exterior wall that convincingly demarcates the boundary of the pavilion. Curved brick walls undulating around the lower level, containing terraces and pools, reinforce this demarcation. Centered over one of these pools, the upper floor entry bridge directs arrival under the canopy of the pavilion, through one pair of the columns exposed to the exterior, and on to the front door recessed between the second set of columns.

On the interior of this piano nobile, a space defined by four curvilinear exploded columns centered at its corners marks the entry foyer with views overlooking the lower level below (Figure 3.5). The immediate view opposite the door reveals a pool of water that continues through the interior on the lower level on axis with the main entry (Figure 3.13). Here, Portman's primary design concept for the house that he describes as "space within space" is first visible in both its functional and formal implications (Portman and Barnett, 1976). Functionally, this water channel that continues from outside to inside and out again acts as a soft boundary distinguishing two spatial hierarchies in the house and thus articulating degrees of privacy. Formally, it becomes clear on the interior that the unusual columns are actually operating as spatial devices throughout the house to support a variety of functions.

Figure 3.5 The interior foyer of the house: Interior view of a column-enclosed stair connecting the upper entry to the living room. . Image © 1977 Jerry Spearman, The Entelechy I Collection, courtesy The Portman Archives.

3.2.1 The Design of the House: Space within Space

The blurred boundaries of exterior and interior in the house are echoed by subtle functional boundaries between the private family and public entertaining zones (Figure 3.4). The asymmetrical entry axis reinforced by the water channel emphasizes that these zones are not bilaterally equal but divided proportional to their use (Figure 3.7 - Figure 3.9). The larger zone is the family area on the west, vertically maintained on both levels of the house as a space of private domesticity including bedrooms, bathrooms, and living spaces (Figure 3.10 - Figure 3.12). A second, double-height public zone to the east can be isolated as an area for entertaining guests in its separate living spaces (Figure 3.14).

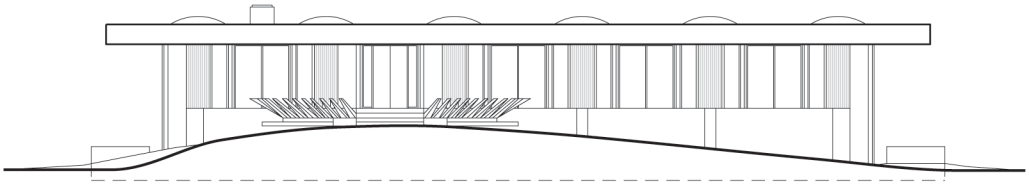


Figure 3.6 North elevation: the entry on the upper level is shown as well as the slope of the drive and lawn that allow for the lower level carport and private entry to the lower level underneath.

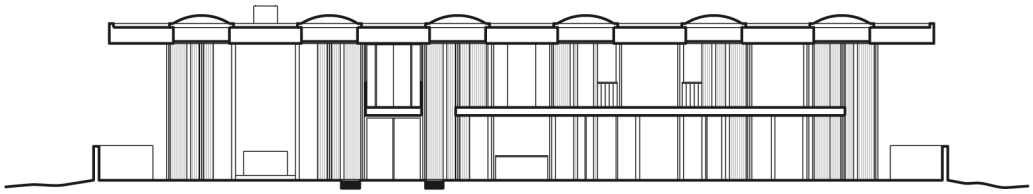


Figure 3.7 Section A, showing five bays from left to right: the first includes the living room looking towards the fireplace, the second is at the entry bridge leading to the front door, and the last three bays form the private family zone.

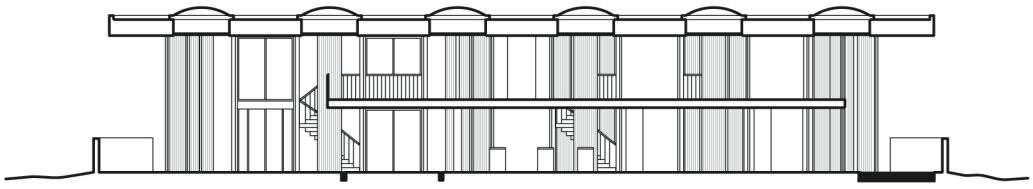


Figure 3.8 Section B, showing five bays from left to right: the first includes the living room looking towards the music room, the second is at the entry foyer, and the last three bays form the private family zone.

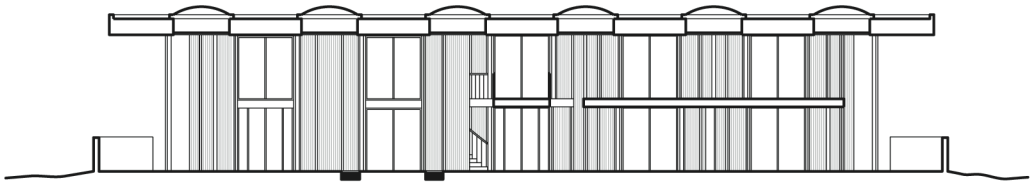


Figure 3.9 Section C, showing five bays from left to right: the first includes the music room, the second is at the water channel next to the master suite, and the last three bays for the private family zone.

Three circulation staircases serve these areas: one for private family use, one exclusive to a loft study over the master bedroom, and one public stair connecting guests from the foyer directly to the entertaining zone of the house.

This zoning creates the possibility for the house to operate as two separate entities at once: a private home for the family and an entertaining showpiece. The private home consists of seven bedrooms and four full bathrooms. Additional family spaces include playrooms, informal living rooms, a family dining room, a study linked to the master bedroom, a laundry room, and the kitchen linking separate dining rooms for both family and entertaining purposes. Within the family zone, four internal hollow columns (including one containing a staircase) are open as light wells extending for the full height of the house, distributing natural light to the interior circulation hall (Figure 3.8). On the lower level, the entertaining spaces of the house in the public zone include the double-height living rooms and a music room as well as the floating dining room beneath the entry foyer. Sliding partitions allow for full separation of the two zones from the centrality of the kitchen.

The form of the house relies on a unique modulation of space organized by the regular repetition of exploded columns within an otherwise open plan. The twenty-four hollow columns thus invent an expansive structural organization throughout the house. This system is as rigorous as it is playful. Portman is ambitious about this dual nature:

> The 8-foot hollow columns in my house created a strong structural order, almost classical in nature, yet left me free to place a variety of different functions and experiences in just two basic kinds of space … Each column is made up of eight separate panels. The ones on the four main axes are structural; the other four can be omitted to meet different conditions. A house is one of the very few building

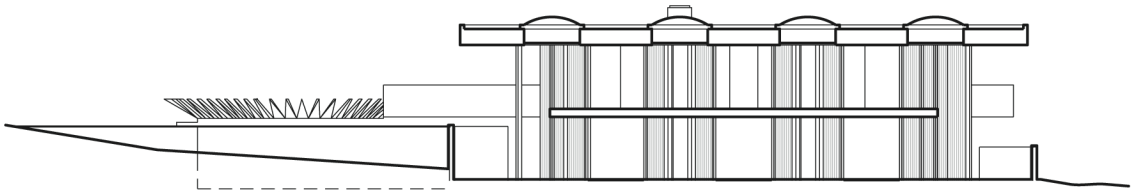


Figure 3.10 Section D, showing three bays of the private family zone.

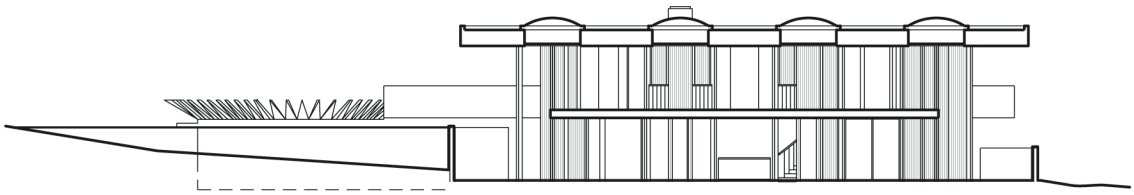


Figure 3.11 Section E, showing three bays of the private family zone.

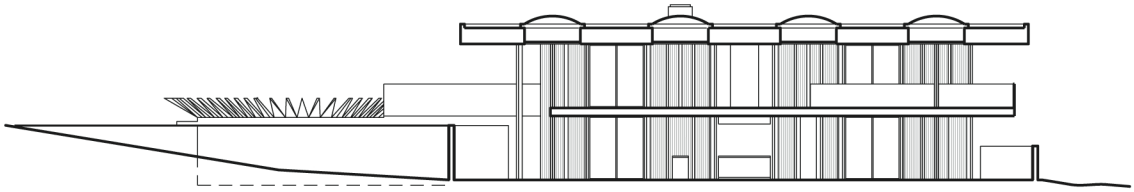


Figure 3.12 Section F, showing three bays of the private family zone.

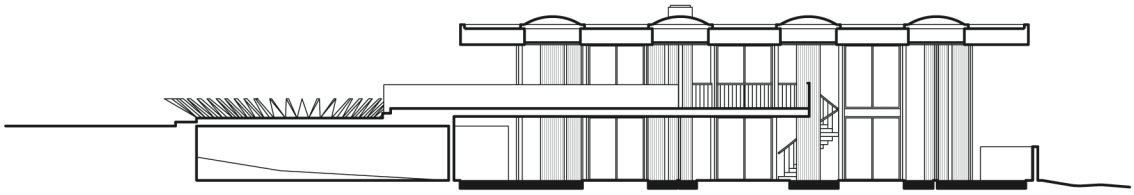


Figure 3.13 Section G. showing the entry sequence of the house.

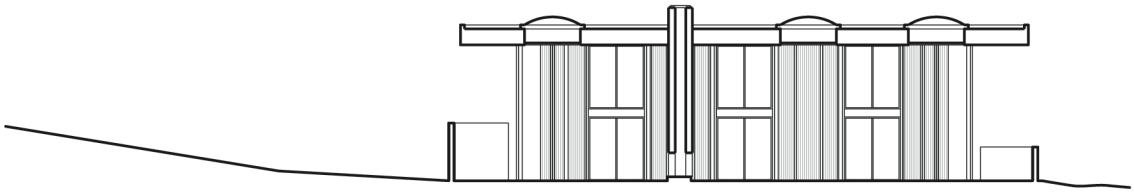


Figure 3.14 Section H, showing three bays of the public entertaining zone.

types that lends itself to the concepts of major and minor spaces as Louis Kahn defined them. The 8-foot diameter of the columns is a dimension large enough to contain the minor functions of the house and to integrate structure, space, light, and ventilation (Portman and Barnett, 1976: 66).

What is striking about this assertion is the tension of distinguishing “spaces that serve from those being served” (Kahn, 1957) in Portman’s conception of minor spaces. Portman sets the minor spaces of the house not as isolated poché, but instead as the foregrounded figures of his composition. In this inversion, the figurative spaces are the so-called minor spaces, defined by hollow columns in a unique stylized spatial expression, and the underlying field space emerges perceptually as the concatenation of major spaces between the hollow columns (Figure 3.4). Significantly, Portman’s hollow column is defined by an eight-foot diameter on its interior, sized precisely to contain a spiral staircase – the most constraining functional requirement among the many within these spaces.

Even more telling here is the relentless repetition of this emergent module of a major space bounded by minor spaces that creates a coordinate unit to characterize the complete arrangement of the plan of the house (Figure 3.15). This coordinate unit allows for the systematic deployment of all sorts of functional and spatial relations between the

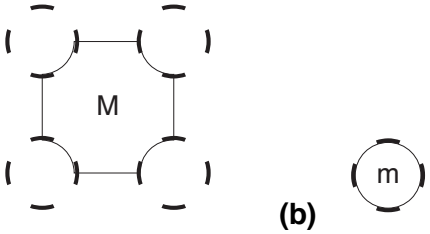


Figure 3.15. Relationships defined by the hollow column: (a) M: major space; (b) m: minor space.

public and private spaces of the house and despite its relentless repetition (or perhaps precisely because of it), it allows for the emergence of a flexible living environment that addresses the subtleties and complexities of the domestic scale. In Entelechy I, this domestic coordinate unit relates the areas of two space types tailored for housing needs at a 1:4 proportion, which works naturally with the functions of a house. A major space, for example a bedroom, is thus easily “served” by a closet or study occupying an adjacent minor space.

Minor spaces are used throughout the house to perforate the complete field of major spaces, providing studies, closets, libraries, half bathrooms, staircases, vestibules, light wells, and art galleries (Figure 3.16 and Figure 3.17). Within these modules, spaces can concatenate to create larger volumes as needed with no impact to the structural frame. Minor spaces group vertically to connect levels, exposing the skylights at the top of each column filtering natural light into the house (Figure 3.17(f)). Major spaces multiply as well, grouping horizontally as halls to access bedrooms, highlighting the fact that within this spatial system there are no conventional corridors. Vertically, major spaces open up as double-height volumes to reinforce the entertaining areas of the house. In all cases, the four structural panels on the cardinal axes of the hollow columns are maintained, establishing a consistent frame for a variety of nested spatial arrangements.

Figure 3.16. Minor spaces utilized in the plan of the house: (a) study; (b) closet; (c) library; (d) half bathroom and coat closet; (e) stair well; (f) light well.

Figure 3.17 Interior views of minor spaces as utilized in the house: (a) study; (b) closet; (c) sculpture gallery; (d) impromptu breakfast area; (e) stair well, images © 1965 Alexandre Georges, The Entelechy I Collection, courtesy The Portman Archives; (f) light well, image © 1981 Jaime Ardiles-Arce, The Entelechy I Collection, courtesy The Portman Archives.

3.2.2 The Geometry of the House: Restructuring the Domestic

The compositional system of Entelechy I is organized to promote both order and variety. The basic arrangement is limited to two primary shapes: the circle and the square. The strict organization of these shapes on a regular grid creates a rigid system, yet the figural hollow columns break this to facilitate diverse spatial conditions in the house defined by two spatial types: minor and major, each related by the circular organization of the column and the square organization of the grid. Aiming to identify the possibilities of

this combination, the composition can be further analyzed not to ascertain Portman's actual intent, but to interpret its more general design implications.

The column is a primary structural and sculptural element of architectural form, regulating loads efficiently and usefully on a regular rhythm. The hollow column reinterprets the compositional properties of a traditional column to employ various programmatic, atmospheric, and experiential possibilities. Instead of a column defined by the point transfer of a single line of force, the load is split across four curvilinear elements that extend the column definition to also enclose a minor space. This upgrades the column into a spatial device articulated by the geometric combination of circle and square. The circle identifies and orders the parts of the hollow column, while the square subdivides them. Although the eight subdivisions of the hollow column relate numerically to the octagon, in Portman's case, it is a layering of two squares that separate the fixed structural panels from the flexible panels of the column by a forty-five-degree rotation. To conjecturally explore this element both within Portman's system and beyond, the full eight-ness will be studied here.

The various possibilities of the exploded column are facilitated by their compositional variation. Breaking the column into eight parts allows for a set of combinations that can be enumerated to calculate the potential of these components and their implied relationships within the space. The number of all non-equivalent configurations of the octagonal symmetry structure of the eight-paneled hollow column can be calculated using Pólya's theorem of counting non-equivalent configurations with respect to a given permutation group (Pólya, 1983). A brief introduction to the theorem and its usage in formal analysis along with complete catalogues for all 2-color configurations of regular n-polygons for $n \leq 12$ is given in Economou and Grasl (2012). The complete number of distinct configurations

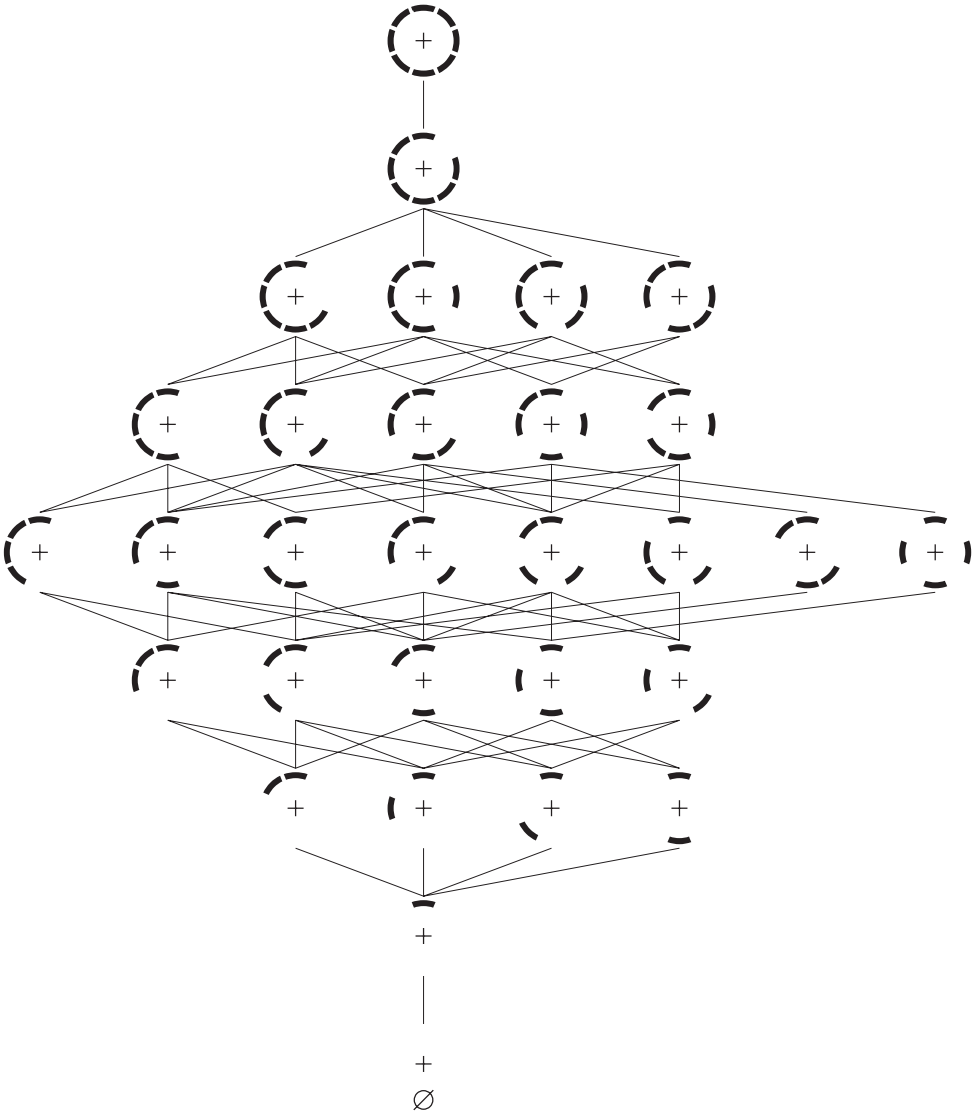


Figure 3.18 Catalog of the thirty non-equivalent configurations of an eight-panel hollow column (*n* = 8).

of eight panels within the hollow column is comprised by thirty possible configurations bounded by the completely enclosed arrangement comprised by eight panels to the entirely open arrangement comprised by no panel at all (Figure 3.18).

While order and variety are achieved within Portman's system, this catalog suggests structural and spatial variations that are not considered in Entelechy I. In practice, these could be composed of a mixture of structural panels, fixed partitions, and operable panels

to expand the performance of the hollow column. Portman's exploded column requires four of these panels to be fixed structural columns to bear loads consistently across the house. Even if this requirement is maintained, but alternate resolutions are allowed, eight variations are possible as shown in Figure 3.19. The last configuration in the row is the

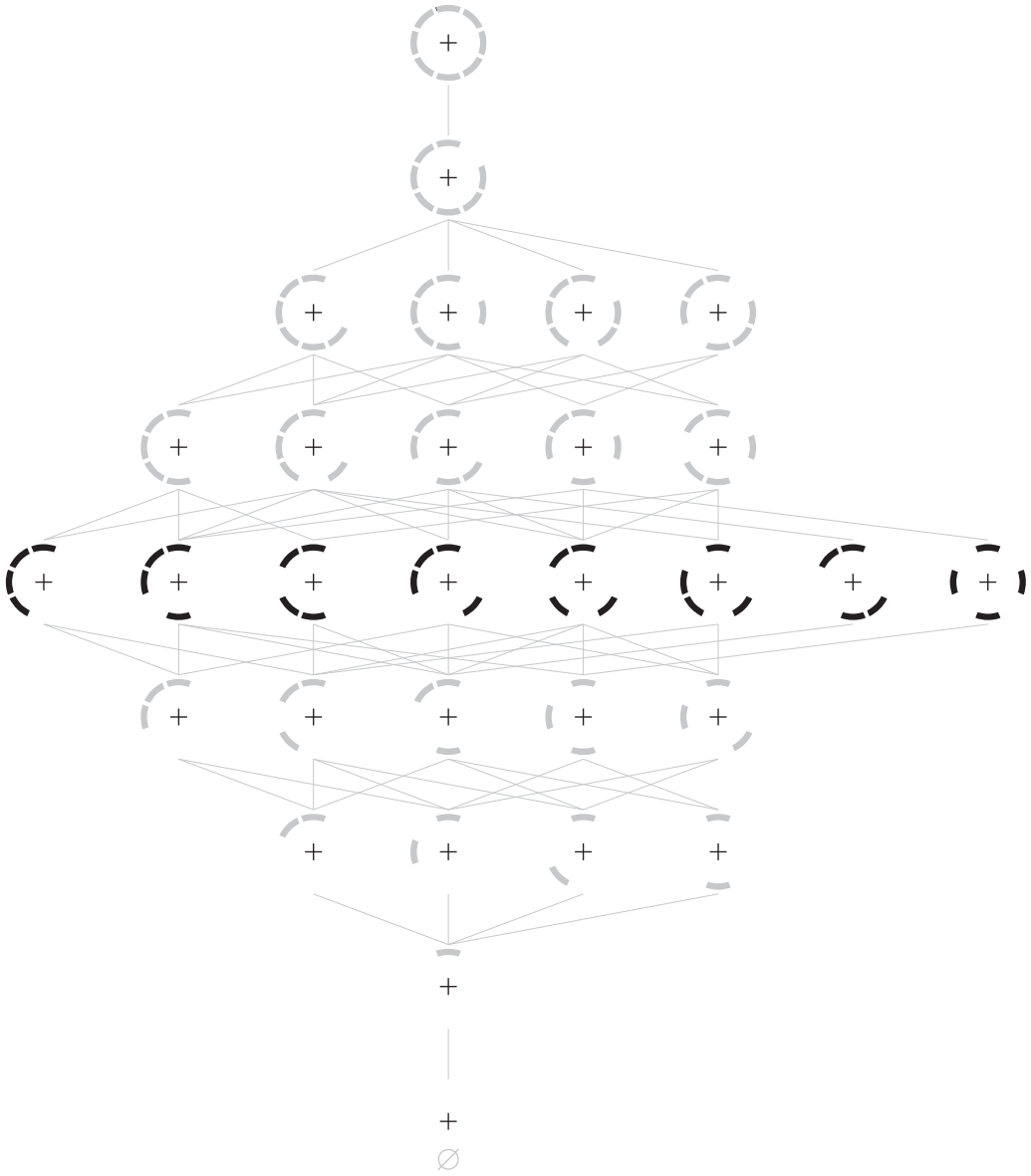


Figure 3.19 Catalog of the eight possible configurations of an exploded column with four fixed structural panels.

consistent fixed structural composition of Portman's exploded column, but even this solution could be explored through rotational variations to consider further potential relationships between minor and major spaces.

Reducing the flexible panels of the hollow column from eight to four by adding Portman's structural constraints produces symmetries captured by the symmetry group of the square (n = 4) and reduces the total number of non-equivalent configurations from thirty to six (Figure 3.20). And still, even though these six configurations are possible in Portman's system, only four are used in Entelechy I. Most notably, strict diagonal connections through the columns like those shown in the last configuration of Figure 3.20, row 3 are avoided in his design. Diagonal connections through the columns are only used in Entelechy I when they branch out and open up to a third or fourth crossing as shown in rows 4 and 5 of Figure 3.20. Also, a column is never entirely closed in the design with all eight panels as shown in row 1 of Figure 3.20. Once these two configurations are eliminated (as denoted in Figure 3.20 by dashed borders), the four hollow column types Portman uses in Entelechy I remain. These four column types can be alternatively characterized in terms of their ratios of openness (1/8; 1/4; 3/8; and 1/2) or inversely to describe their solidness (7/8; 3/4; 5/8; and 1/2) to aid in understanding their deployment within the overall plan of the house.

The circular columns are arranged within a square grid to create the basic system of organization in the house. The grid is the organizing system par excellence of modern architecture, regulating space efficiently and usefully within a set module. Grids are less strictly applied in domestic architecture than in commercial work, especially in single-family homes where the desire for a variety of room sizes often eliminates the practicality of an equally spaced structural grid. Nonetheless, Portman's use of an underlying square

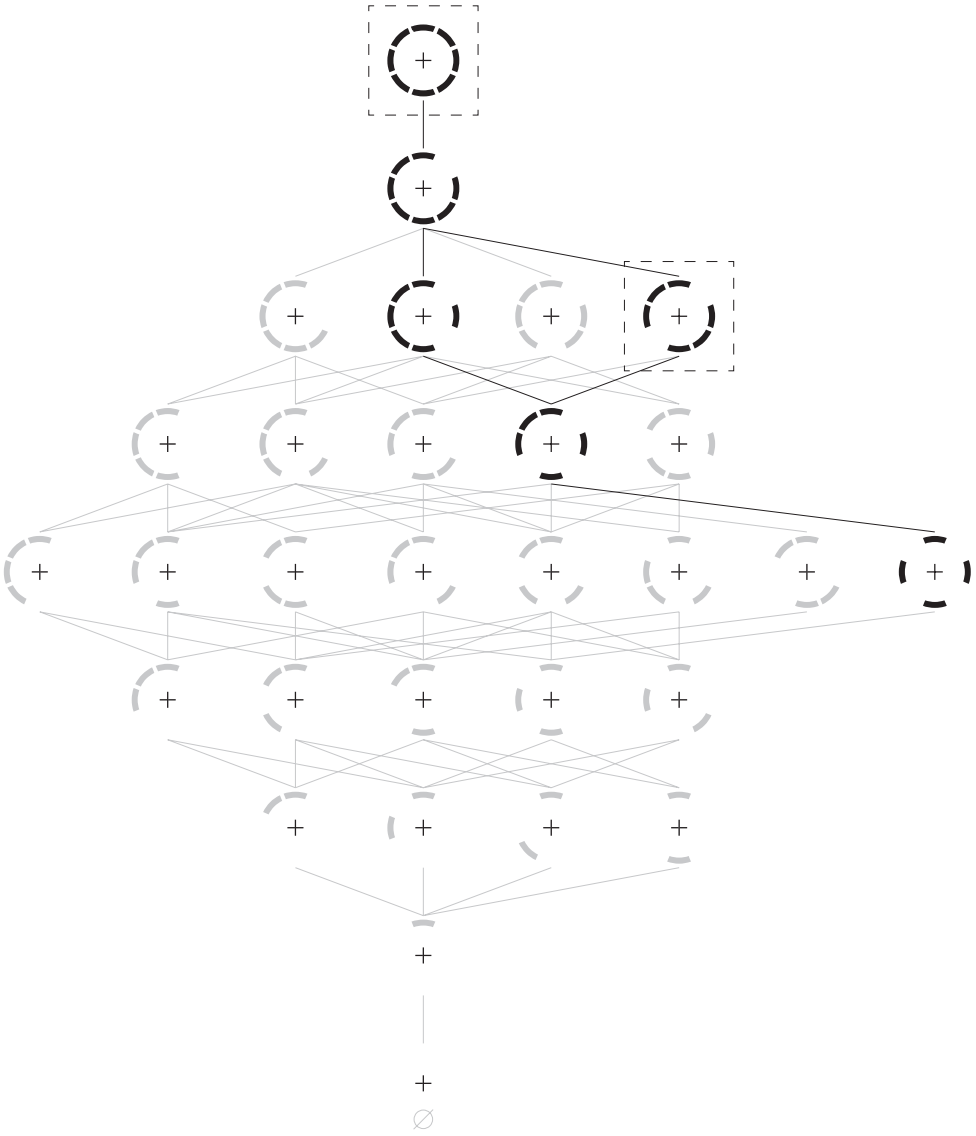
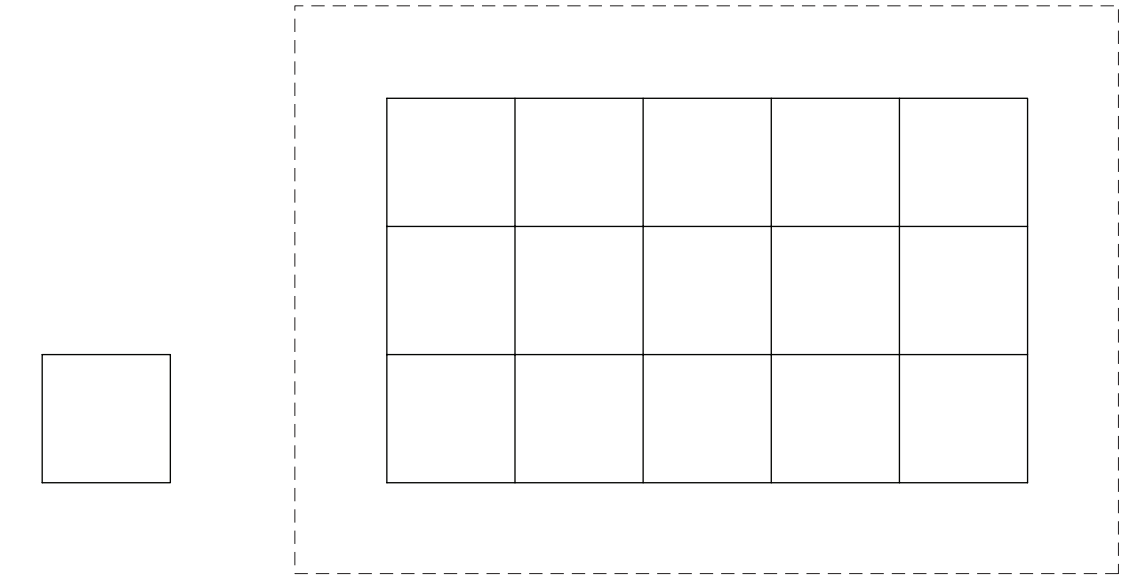


Figure 3.20 Catalog of the six possible variations of a hollow column possible within Entelechy I's configuration when four fixed structural panels are required. The two configurations with the dashed border are not present in the house.

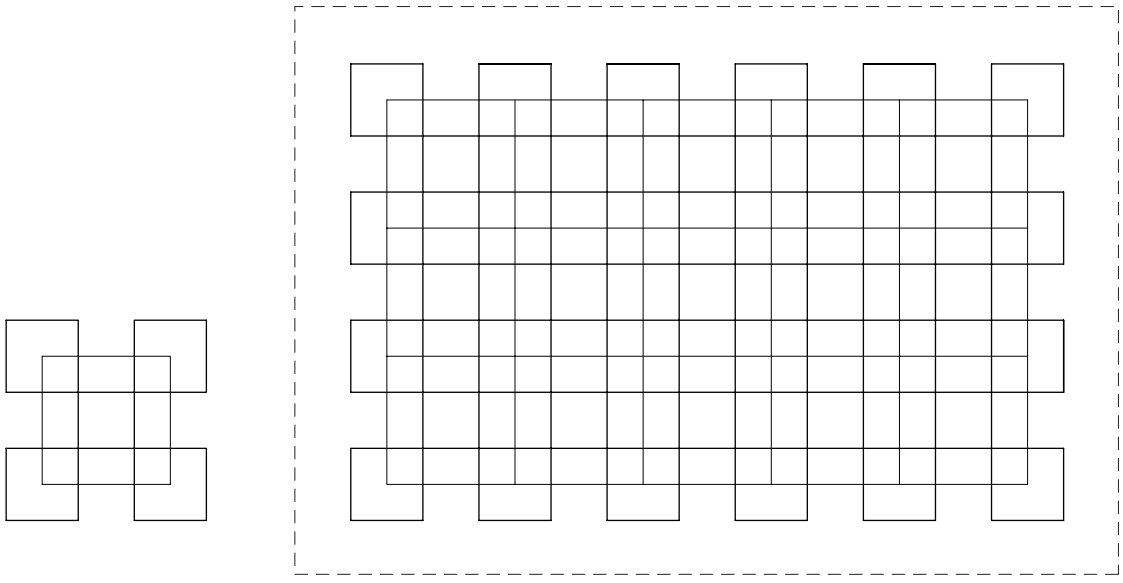
grid in Entelechy I provides a canvas that combines with the figural minor grid to propose a domestic coordinate unit that modulates a layered framework of spaces for residential applications.

The underlying grid is defined by a module of major space and an overall specification for the growth of that module to define a complete boundary condition for a design. Grids are specified in terms of *n* x *m* cells, where *n* describes the number of modules defining the overall depth and *m* describes the number of modules defining the overall width. Entelechy I is composed of a 3 x 5 grid creating a rectangular framework – a numerical proportion that recalls the "ideal villas" analyzed by Rowe (1947). However, in these ideals both Palladio and Le Corbusier use tartan grids of alternating widths within their 3 x 5 structures rather than Portman's consistent 3 x 5 grid. The square module (Figure 3.21(a)) creates this consistency as shown in the simplified grid of Entelechy I in Figure 3.21(b), where the dashed rectangle offset from the overall figure represents the platform roof outline above. Portman's grid gains its tartan qualities with the further addition of a minor grid as shown in the module of Figure 3.21(c) and its 3 x 5 resolution in Figure 3.21(d).

Once the circular figures are added to the grid, a new set of relationships come forward. Portman's composition of a square grid combined with the circular figure resolves the regularity of the grid module to work for the functions of a house and establishes the spatial relations of his domestic coordinate unit. Figure 3.22(a) illustrates a single module of this unit in its simplified geometry, where the emergent eight-sided figure of the major space is clarified. When repeated on the 3x5 grid to match the arrangement of the house, the plan diagram of Figure 3.22(b) is achieved. The alternating sequences provided by

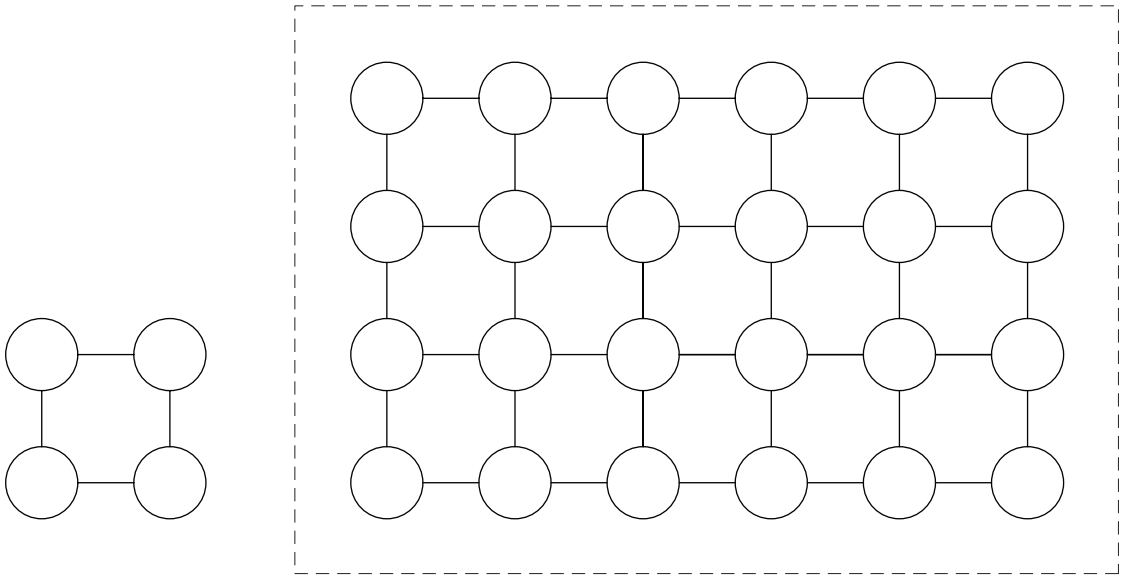


(a) module *(b) 3 x 5 grid*

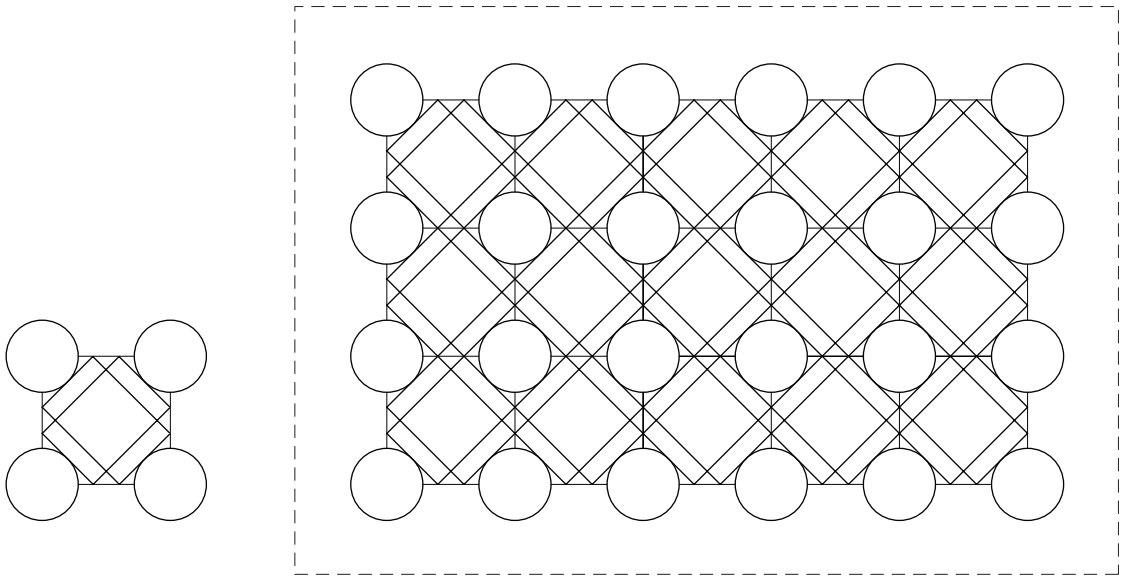


(c) module *(d) 3 x 5 grid*

Figure 3.21 Plan diagrams illustrating the grid modules and their aggregation in the 3 x 5 grid of Entelechy I: (a) square/major module; (b) square/major 3 x 5 grid; (c) tartan major/minor module; (d) tartan 3 x 5 grid.



(a) module *(b) 3 x 5 grid*



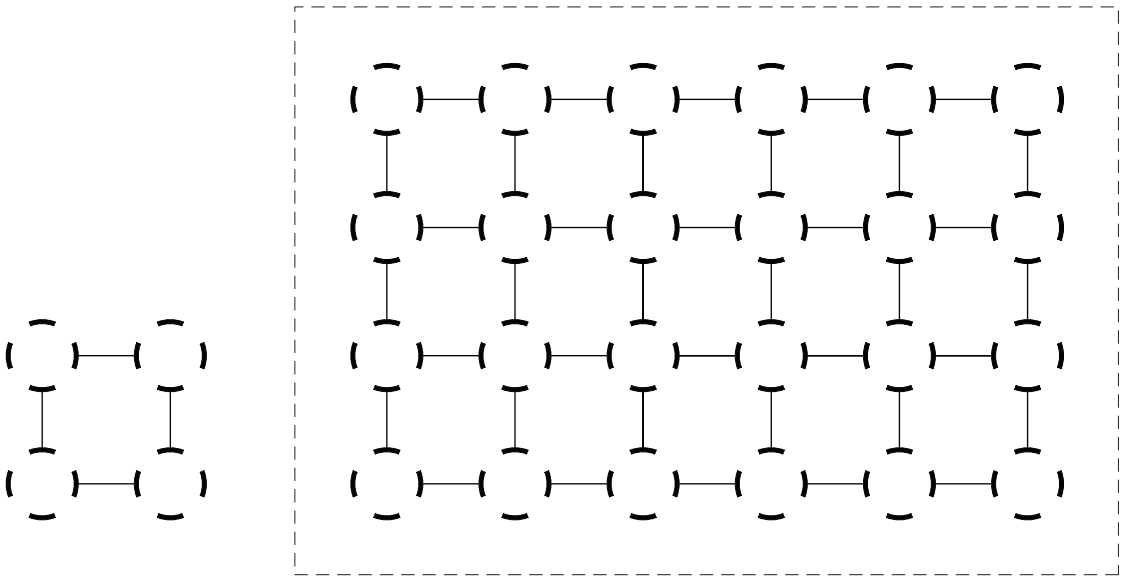
(c) module *(d) 3 x 5 grid*

Figure 3.22 Plan diagrams illustrating the figures and thresholds achieved by the aggregation of circular figures on the square grid of Entelechy I: (a) figure module; (b) figure module on 3 x 5 grid; (c) diagonal threshold module; (d) diagonal thresholds on 3 x 5 grid.

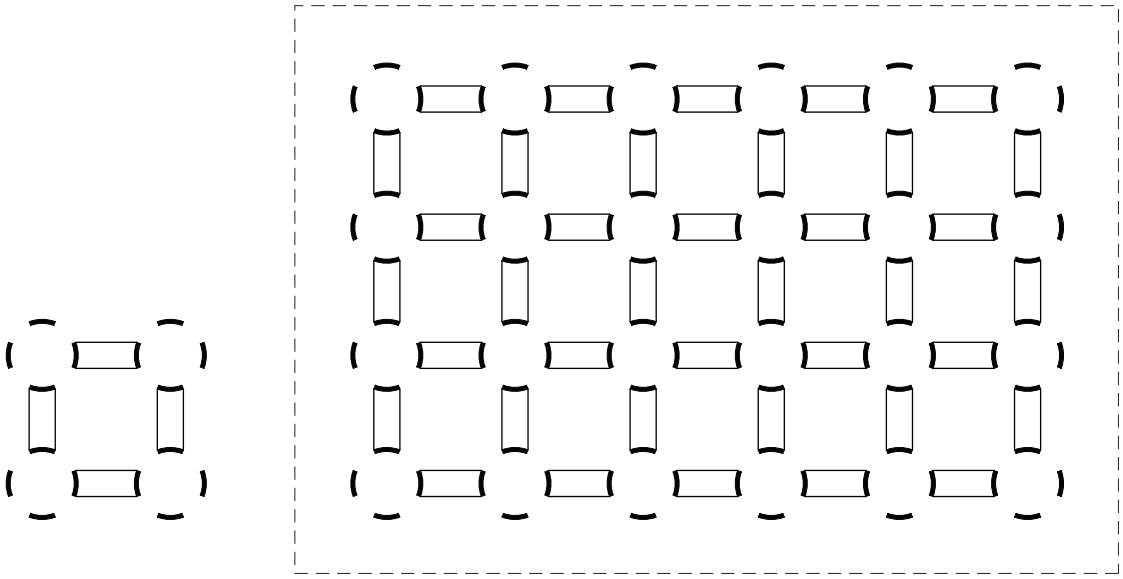
this layering of major and minor frameworks adds complexity and flexibility to the house that can be illustrated further by delineating emergent thresholds. These conceptual delineations suggest diverse visual readings and experiential connections across the spaces as coordinate units multiply in a larger aggregate pattern in the house. For example, the thresholds that filter connections diagonally across the coordinate unit, shown in Figure 3.22(c), aggregate as elongated threads across the 3 x 5 arrangement (Figure 3.22(d)). Without corridors per se, the perforations created by the combination of these figures and thresholds create a pliable circulation system for people, air, and light.

This arrangement builds in complexity as the features of the hollow column are incorporated within the 3 x 5 grid. An initial study to assess this is given in Figure 3.23, where in (a) and (b) the four structural parts of the exploded column are added to the module and 3 x 5 grid, respectively. The corollary diagrams of (c) and (d) illustrate how these four parts create another series of perpendicular emergent thresholds in each module and across the overall composition. The floor plans of the house (Figure 3.4) confirm that these perpendicular thresholds are the basis for all of the straight partitions in the house and their further subdivisions, whether thin glass walls at the perimeter, countertops in the kitchen, or thickened storage areas between rooms.

The conditional relationships between the hollow column configurations provide another lens to understand the specificity of column arrangement in Entelechy I. These variations are nicely captured by the isovist fields that denote the volume of space that is visible from a given point in space (Benedikt, 1979). The isovist diagrams of Figure 3.24 show these connections across the grid by radiating lines from the twenty-four center points of the hollow columns to imply their greater volumetric influence. These abstractions are overlaid on the plans of Entelechy I to clarify the subtleties of their functional and

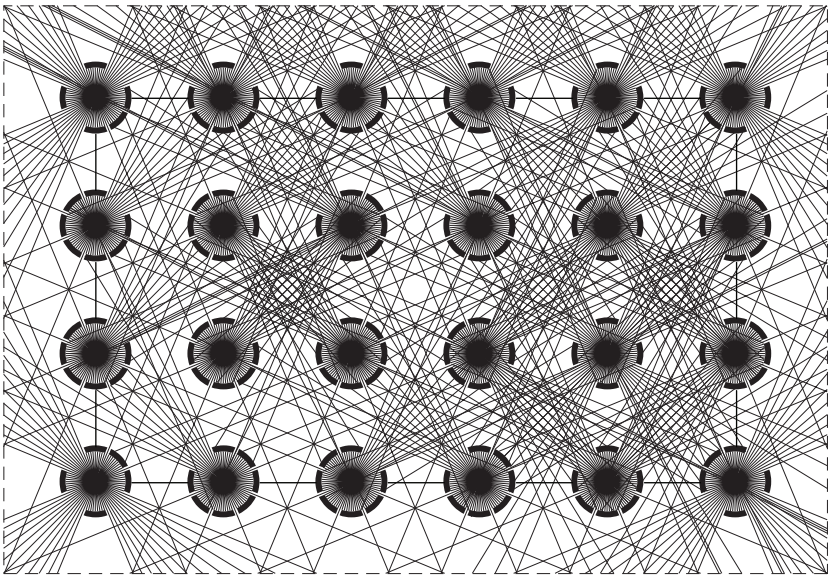


(a) module *(b) 3 x 5 grid*

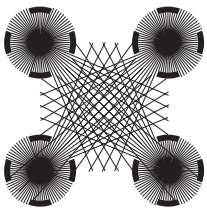


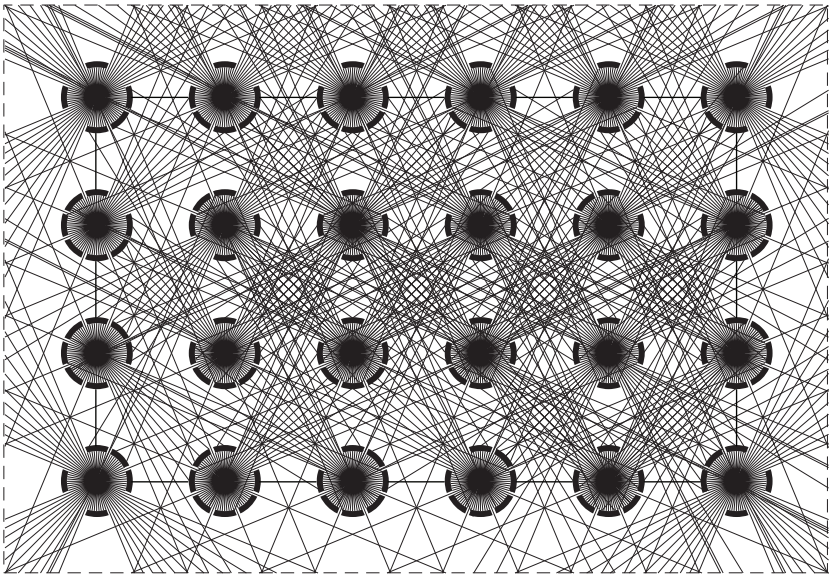
(c) module *(d) 3 x 5 grid*

Figure 3.23 Plan diagrams illustrating the addition of the four structural parts of the exploded columns of Entelechy I: (a) structural module; (b) structural module on 3 x 5 grid; (c) perpendicular threshold module; (d) threshold module on 3 x 5 grid.



(b) Entelechy I, upper level





(a) module

(c) Entelechy I, lower level

Figure 3.24 Isovist plan diagrams illustrating the visual and volumetric relationships of the hollow columns in Entelechy I: (a) structural isovist module; (b) upper floor (main entry level) plan; (b) lower floor plan.

formal composition in a simple module based on the structural elements (Figure 3.24(a)), as well as the complex realities of the upper level (Figure 3.24(b)), and the lower level (Figure 3.24(c)) arrangements in the house. The patterning of the perimeter columns includes distinct configurations at the exterior corners and a visible difference in the treatment of the front of the house versus the back and sides. More precisely, if we consider the perimeter columns in terms of the ratios of openness described previously (1/8; 1/4; 3/8; and 1/2), the exterior corner columns (including those at the recessed entry) are always the 3/8 configuration oriented to be closed to the interior and open to the exterior; the remaining front columns are the 1/4 configuration oriented to be closed to the interior and open to the exterior, and columns at the back and sides are the 1/4 and 1/8 configurations oriented in an opposite relation so that they are open to the interior and closed to the exterior. On the interior all four column configurations are utilized to reinforce the central halls as connective spaces. Similarly, the various densities of crossing lines in the major spaces of the diagrams visually reinforce the private family and public entertaining sides of the house where private spaces naturally offer less connection in comparison to public spaces.

These geometric systems describe the design strategies of the house as dependent on the interrelation of function and form. Functionally, public and private spaces are arranged in the house to reflect a variety of domestic modalities supported by a consistent coordination. Horizontal and vertical circulation within these spaces is likewise deployed to support these distinctions. Formally, the combination of minor and major, column and grid, provides a field for multiple events and spaces within a multivalent composition. These dynamic “minor” figures are expressive as structure, skin, circulation, threshold, and more – articulating the potential of the domestic coordinate unit.

3.3 After the House

The secondary corpus includes designs that Portman associated with the house, either indirectly by association in the catalog of works published in *The Architect as Developer* or directly by name. The indirect series follows the concept of ”organizing principles that work for a room or a restaurant, a building or a group of buildings” (Portman and Barnett, 1976:64) by studying designs that relate to each of these categories. The corpus includes: the interior design of the Midnight Sun Cocktail Bar; the hospitality designs of the atria hotels (specifically: a) the Hyatt Regency Atlanta, b) the Hyatt Regency O’Hare, and c) the Marriott Marquis Times Square); and the urban design of the Detroit Renaissance Center. The final design of the corpus, Portman’s 1986 beach house Entelechy II, is directly related to the 1964 house by program and name, defining a reflective moment in the evolution of Portman’s architectural language (Portman, 1997).

3.3.1 The Midnight Sun Cocktail Bar

Portman’s architecture has been characterized as one that is organized entirely for interiority at all scales (Rice, 2016), suggesting that his interior design for a room is essential to the study of his formal language. The singular space studied in detail here is Portman’s 1968 design for the Midnight Sun Cocktail Bar (Figure 3.25). The bar is a room within the larger design for the Midnight Sun restaurant, which was built on the lower level at Peachtree Center (Atlanta, GA, USA). An interior image of the bar is given in Figure 3.26, where the radial layout of the room is established by a central column with a circular bar surrounding it. The column is covered in wooden slats that are formed to radiate out across the ceiling, evoking a treelike canopy that reinforces the circular form. Around this central core, private seating pods are arranged at the perimeter to provide a sense of

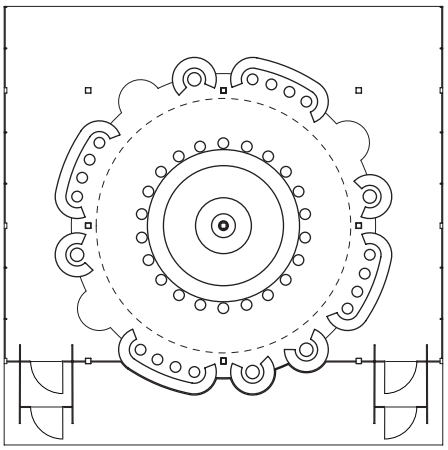


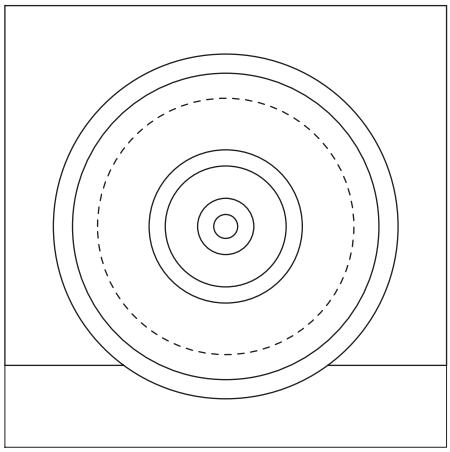
Figure 3.25 Floor plan of the Midnight Sun Cocktail Bar.

Figure 3.26 Midnight Sun Restaurant: interior view of the cocktail bar. Image © 1968 Alexandre Georges, The Midnight Sun Collection, courtesy The Portman Archives.

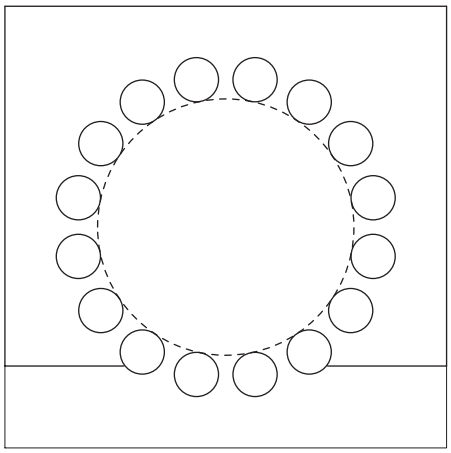
enclosure. These seating pods are developed in two sizes - one for an intimate curvilinear banquette around a single central table, and a second elongated double banquette that provides shared seating at four smaller tables. Each of these seating zones are semi-enclosed by a series of vertical wooden slats that wrap the curvilinear seating to screen the bar area, defining the perimeter of its separate space within the restaurant. This perimeter pattern is broken to facilitate circulation access in and out of the bar for patrons and restaurant service.

Portman describes the design as “a system of niches and pockets of space that give individual tables their own private environment … Space is allowed to flow in such a way that you can see from the cocktail lounge in the front all the way to the opposite end of the restaurant; yet you are always in your own intimate area. This duality is achieved by space modulation.” He discusses the Midnight Sun design in direct relation to Entelechy I, linking the two projects in terms of an interest in achieving both a strong sense of order and an equally strong potential for diversity through geometric arrangement (Portman and Barnett, 1976: 68). This geometric organization and resulting subdivision are analyzed in a series of diagrams shown in Figure 3.27. First, the central organization of the design is emphasized in Figure 3.27(a) within the context of the square tenant space of the base building. Next, two diagrams illustrate boundary subdivisions of the perimeter into sixteen (Figure 3.27(b)) and eight parts (Figure 3.27(c)), relating the two types of seating pods used in the design. The final diagram shows how these dual modules of subdivision combine to create an alternating pattern, layering divisions of four, eight, and sixteen.

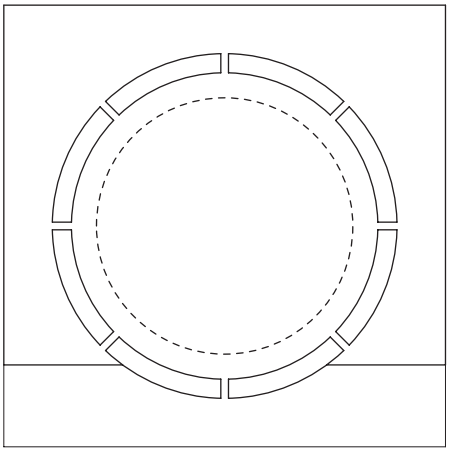
Once this underlying organization is considered, the composition of the seating and circulation are studied in the diagrams of Figure 3.28. The two types of seating pods are elaborated in the diagrams of Figure 3.28(a) and (b), illustrating how the double



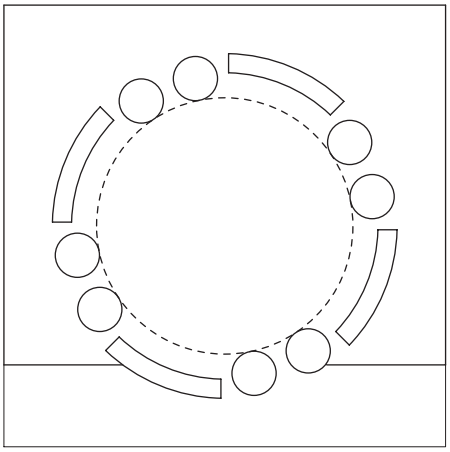
(a) central circular organization



(b) boundary subdivision_16



(c) boundary subdivision_8

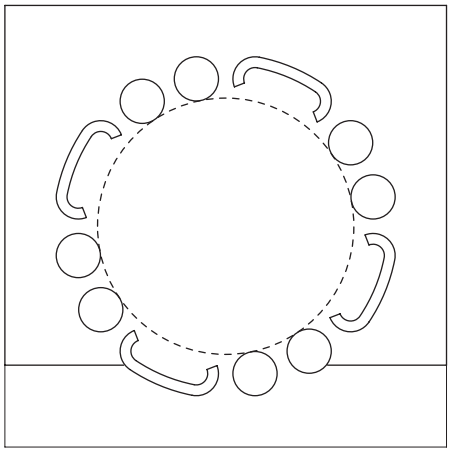


(d) alternating arrangment_4:8:16

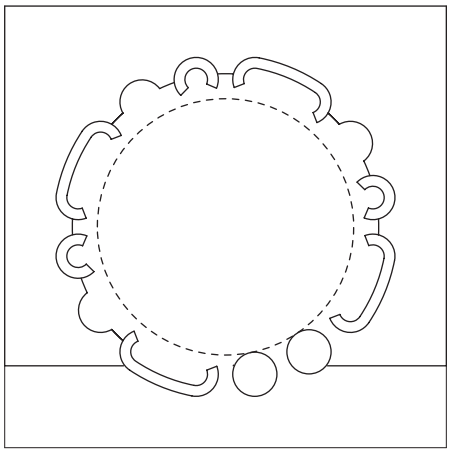
Figure 3.27 The Midnight Sun Cocktail Bar: overall organization and subdivision diagrams.

banquette and single banquette relate to subdivisions of eight and sixteen, respectively. Figure 3.28(b) illustrates the addition of three single banquette pods that are each paired with a break in the perimeter definition to allow for circulation access to the central space. This is one of two arrangements of the single banquette used in the design. The second

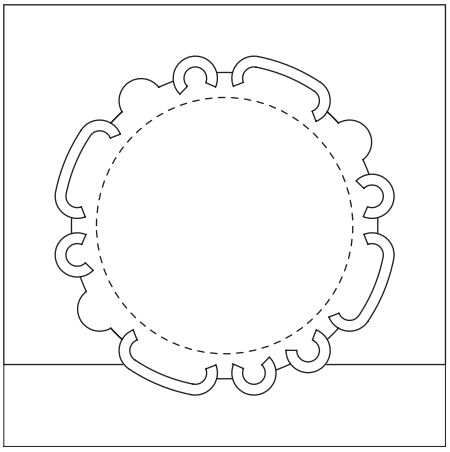
Is shown in Figure 3.28(c), where two single banquettes are paired to close the perimeter gap where it intersects the glass enclosure of the tenant space, represented by a single horizontal line in the diagram. The final diagram of Figure 3.28(d), depicts the addition of tables and the central bar area to clarify the complete arrangement of the interior design for the cocktail bar.



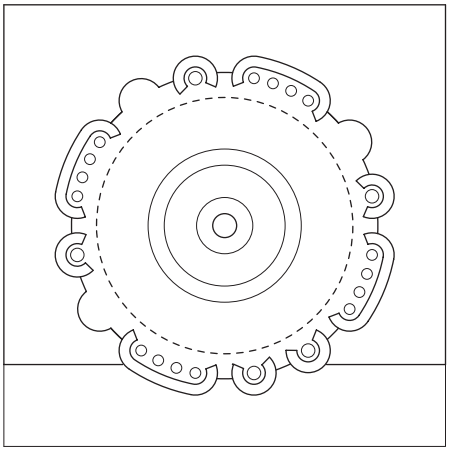
*(a) seating pod 1_*
double banquette



*(b) seating pod 2a_*
single banquette + circulation



*(c) seating pod 2b_*
pair of single banquettes



*(d) layered boundary arrangement_*
seating + circulation

Figure 3.28 The Midnight Sun Cocktail Bar: seating and circulation diagrams.

3.3.2 The Atrium Hotel

Hospitality designs – and particularly the atrium hotels – are the backbone of Portman's architectural practice. In these projects, Portman repeatedly used the atrium in response to hotel programs to create many of his most compelling and memorable spaces, setting the tone for principles of architectural hospitality imitated worldwide. Portman argues in these works that this design approach is good for architecture, development, and social relations.[72] Still, when Portman began working on a speculative design-development for a hotel in downtown Atlanta, his original scheme included a narrow, conventional tower of guestrooms arranged on a double-loaded corridor. In the second scheme, he reworked his ideas entirely:

> I didn't want the hotel to be just another set of bedrooms. The typical central-city hotel had always been a cramped thing with a narrow entranceway, a dull and dreary lobby for registration, elevators over in a corner, a closed elevator cab, a dimly lighted corridor, a nondescript doorway, and a hotel room with a bed, a chair, and a hole in the outside wall. That was the central-city hotel. I wanted to do something in total opposition to all this. I wanted to explode the hotel; to open it up; to create a grandeur of space, almost a resort, in the center of the city. The whole idea was to open everything up; take the hotel from its closed, tight position and explode it; take the elevators and literally pull them out of the walls and let them

[72] A lesson first learned on a public housing project, the Antoine Graves Homes (Atlanta, GA, USA). Completed in 1965, the design is centered around a pair of covered, open-air courts on the interior, each envisioned as an enlarged, collective porch for the elderly residents. The atria provided opportunities for cross-ventilation to all of the units, natural light to the interior courts, and a social space – all within the constraints of a low-income housing program. Portman discusses the project as one that made him realize that design possibilities beyond the typical program could be cost effective while simultaneously providing spatial and social amenity to the project. Portman and Barnett, 1976: 28.

> become an experience within themselves, let them become a giant kinetic sculpture (Portman and Barnett, 1976: 28).

This opposition was materialized in Portman's first atrium hotel, the speculative building that opened in 1967 as the Hyatt Regency Atlanta. The design features guestrooms that surround the atrium space, a concept Portman describes as one of "shared space," referencing Frank Lloyd Wright's Guggenheim Museum as a precedent where this principle is exhibited to create an experiential architecture activated by the movement, observation, and activity of people (Portman and Barnett, 1976: 117). This arrangement supports the two extreme scales of hospitality design so that modular guestrooms (and their supporting systems of plumbing and structure) are conveniently organized around a grand, collective space reserved for larger scale amenity functions that can be echoed below as well as above the atrium.

The design was the prototype for a series of atrium hotel projects where variations and oppositions to the form became a source of ongoing formal development. To address the organization of the atrium hotel more generally here, three of these designs will be studied including the original prototype. Together, the set includes: a) the 1967 Hyatt Regency in Atlanta, Georgia (Figure 3.29; Figure 3.30); b) the 1971 Hyatt Regency O'Hare in Chicago, Illinois (Figure 3.31; Figure 3.32); and c) the 1985 Marriott Marquis Times Square in New York, New York (Figure 3.33; Figure 3.34). A broader study on the hospitality corpus is pursued because the hotels were Portman's most prolific works where he continued to repeat, rework, and research the atrium design. Each of the atria hotels selected for the corpus are represented with a typical guestroom plan. These three designs are chosen for their shared conceptual arrangement around a rectilinear atrium, allowing for a closer comparative study on the details that produce a unique variation.

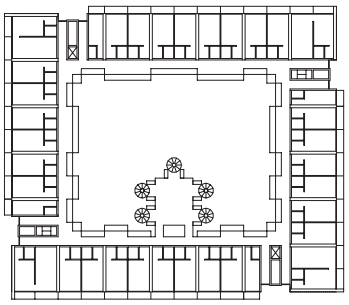


Figure 3.29 Typical guestroom floor plan of the Hyatt Regency Atlanta.

Figure 3.30 Hyatt Regency Atlanta: worm's eye view of the atrium. Image © 1989 Michael Portman, The Hyatt Regency Collection, courtesy The Portman Archives.

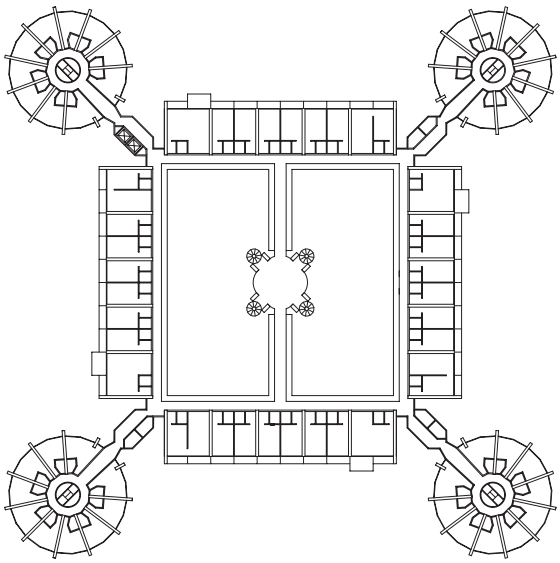


Figure 3.31 Typical guestroom floor plan of the Hyatt Regency O'Hare.

Figure 3.32 Hyatt Regency O'Hare: interior view of the atrium. Image © 1971 Alexandre Georges, The Hyatt Regency O'Hare Collection, courtesy The Portman Archives.

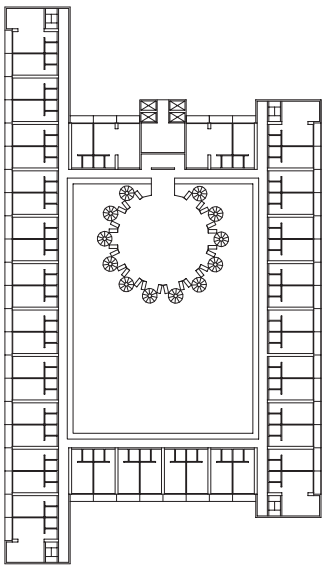


Figure 3.33 Typical guestroom floor plan of the Marriott Marquis Times Square.

Figure 3.34 Marriott Marquis Times Square: worm's eye view of the atrium. Image © 1989 Bo Parker, The New York Marriott Marquis Collection, courtesy The Portman Archives.

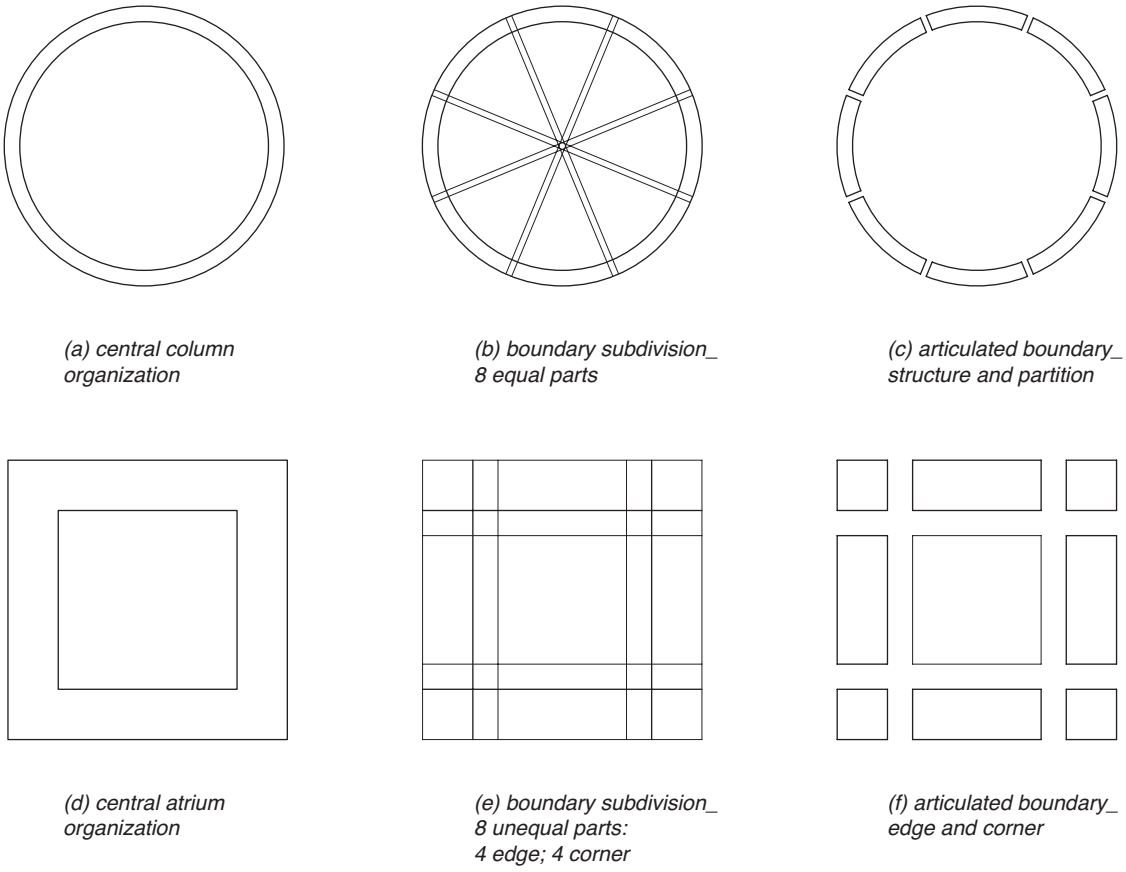
Portman's hospitality atria essentially "(re)invent the atrium," creating an interior urbanism defined by hollow forms (Koolhaas 1995; Rice, 2016). Upon reflection, Portman describes the design as directly related to the design of Entelechy I:

> In the early sixties I first started exploring the idea of expressing our atomic era with its hovering consciousness of existence in an age of "controlled explosion." This led philosophically to focus on separation – fragmentation – splitting – floating and outward movement, both physically and socially. This thought process played a major role in the evolution of the exploded column in the design of Entelechy I, our first house in Atlanta, and the Hyatt Regency Atlanta, the first major atrium hotel, both of which were then in the design stage … In both, the exploded column and the atrium, space within space was created while moving structure to the exterior skin of the circumference – integrating functional space, structure and circulation – while creating and exposing a unique spatial element – breaking the mold of compressed architecture (Portman, 1997: 10).

The geometric organization and subdivision to create "space within space" is analyzed in a series of diagrams shown in Figure 3.35 to visually relate the exploded column and the atrium hotel following the transformations Portman describes.[73] The central organization of the column and atrium, each with a space inscribed inside, are illustrated in the double bounded circle and square diagrams of Figure 3.35(a) and (d). The second pair of diagrams, Figure 3.35(b) and (e), show the subdivision of the perimeter boundary of column and atrium, both broken into eight parts with thickened reveals offset between each part. In the column, these parts are equal, arranged radially with a small gap in

[73] These studies are a development of an earlier take on the relationship between the column and the atrium hotel that focused primarily on the Atlanta Hyatt Regency (Ligler and Economou, 2019a).

between to articulate their subdivisions. Alternatively, in the atrium these subdivisions are unequal. This inequality distinguishes edge and corner conditions, whose reveals intersect to allow for a central circulation zone around the atrium – and continue as linear extensions from the central ring to meet the perimeter. The final pair of diagrams, Figure 3.35(c) and (f), illustrate how the combination of central organization and subdivision in column and atrium produce an articulated boundary. This allows for the further distinction of four structural and four spatial partitions in the hollow column as used in the design of Entelechy I. In the hollow atrium, this clarifies four edges, four corners, and connected gaps in between to define a system for organizing the typical guestroom floors of the hotel.



(a) central column organization

(b) boundary subdivision_ 8 equal parts

(c) articulated boundary_ structure and partition

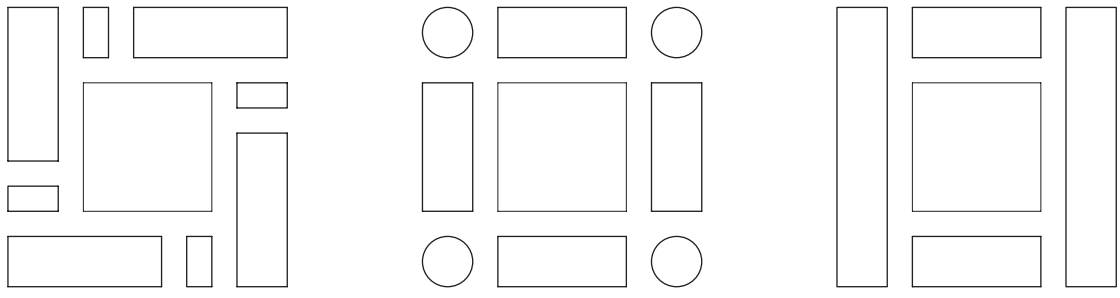
(d) central atrium organization

(e) boundary subdivision_ 8 unequal parts: 4 edge; 4 corner

(f) articulated boundary_ edge and corner

Figure 3.35 From Column to Atrium: organization, subdivision, and boundary diagrams.

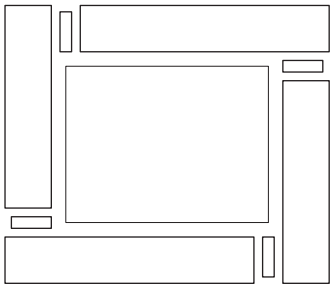
With the boundary arrangement understood as an edge/corner articulation, the three hotels of the corpus can be conceptually analyzed as variations of these relations. The three diagrams of Figure 3.36 depict this, showing each hotel as a study in edge and corner treatment to bound the atrium under a series of symmetrical relations in the overall composition. In this comparative analysis, the Hyatt Regency Atlanta (Figure 3.29) maps to the cyclic symmetry of Figure 3.36(a), where four edges are translated to meet the corner and the four "corner" pieces shift to align with the interior corners of the central atrium. Building on this construction, the second diagram of Figure 3.36(b) maps to the Hyatt Regency O'Hare (Figure 3.31), where dihedral symmetry maintains the four edge and four corner pieces defined in the initial construction of Figure 3.35(f) with a simple substitution of the square corners for circular ones. Lastly, the third diagram in Figure 3.36(c) maps to the Marriott Marquis Times Square (Figure 3.33), where the four corners are absorbed in two elongated edges, each facing the other, creating a bilaterally symmetrical organization in the overall design. This arrangement creates two "fixed" shorter edges that span between the longer edges, which can each be customized to expand beyond the fixed edges as desired to resolve a specific program, site, or aesthetic.



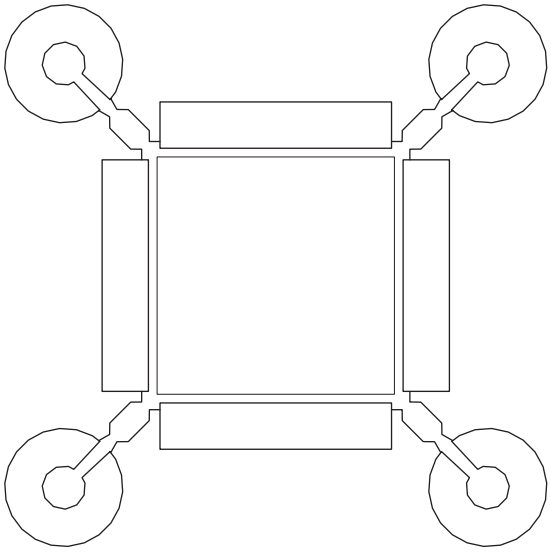
(a) cyclic symmetry *(b) dihedral symmetry* *(c) bilateral symmetry*

Figure 3.36 The Atrium Hotel: three variation on edge and corner treatment bounding the central atrium.

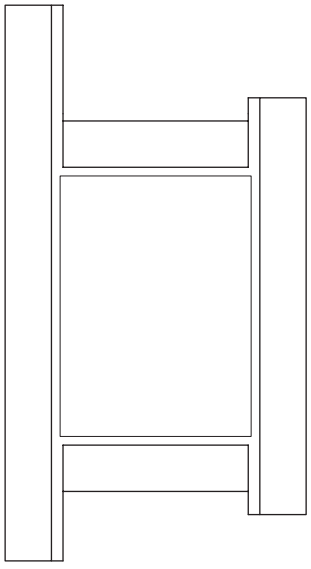
These three arrangements are parameterized in the diagrams of Figure 3.37 and Figure 3.38 to map more precisely to the details of each configuration in the atrium hotel corpus. When compared to each typical guestroom plan, these diagrams aid in mapping the guestroom “edge” zones in comparison to the “corners,” which resolve different functional and formal interests in each design. All of these arrangements are precisely regulated in terms of half and whole guestroom modules included in the diagrams of



(a) Hyatt Regency Atlanta

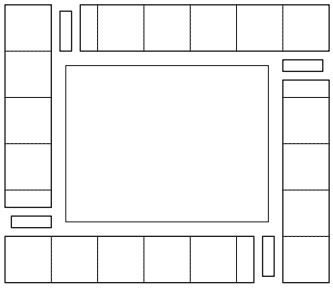


(b) Hyatt Regency O’Hare

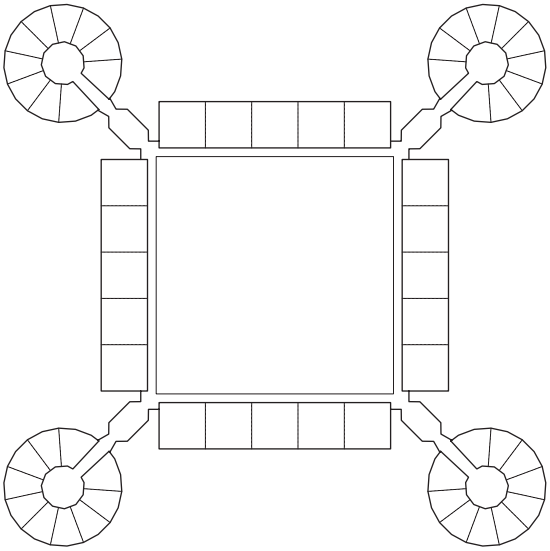


(c) Marriott Marquis Times Square

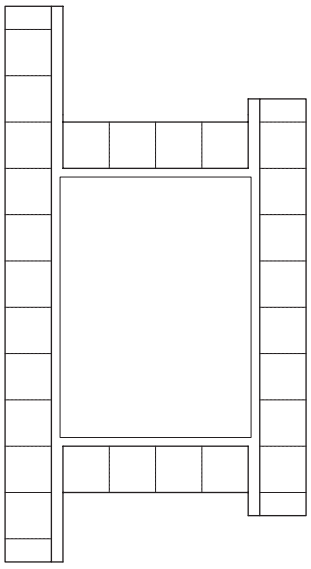
Figure 3.37 The Atrium Hotel: edge and corner diagrams describing the boundary of the central atrium in each design.



(a) Hyatt Regency Atlanta



(b) Hyatt Regency O'Hare



(c) Marriott Marquis Times Square

Figure 3.38 The Atrium Hotel: guestroom module diagrams describing the primary hospitality parameters in each design.

Figure 3.38.[74] In the Hyatt Regency Atlanta (Figure 3.29), the "corners" become offset rectangular zones for alternating egress and service circulation as clarified in the diagram of Figure 3.37(a), resulting in a half-guestroom module at the adjacent end of each shifted

[74] In hospitality design, guestroom modules describe a pair of guestroom keys, or two separate rooms, which are typically organized to depend on shared mechanical, electrical, plumbing, and structural systems efficiently. Expanding on this logic, a half-guestroom module is typically a single guestroom and guestroom suites (not considered here) are composed of multiple modules in a hospitality program.

guestroom “edge” as shown in the diagram of Figure 3.38(a). The arrangement in Chicago (Figure 3.31), develops the “corners” as extensions for four egress circulation towers (Figure 3.37(b)) that simultaneously increase guestroom capacity with radially modulated guestroom cylinders as depicted in Figure 3.38(b). Alternatively, in New York (Figure 3.33), the “corners” on the long edges extend to elongate the overall expression, resulting in a bilaterally symmetrical interior arrangement relative to the atrium within an asymmetrical composition in the overall design as shown in Figure 3.37(c). The modular analysis of Figure 3.38(c) illustrates how these extensions map to additional guestroom modules, with each long edge terminating in a half-module for egress that allows for four staircases to be located at the ends of the longer corridors. Together these diagrams emphasize variations on edge, corner, and module that establish the primary organizational geometries of the atrium in Portman’s hotel design.

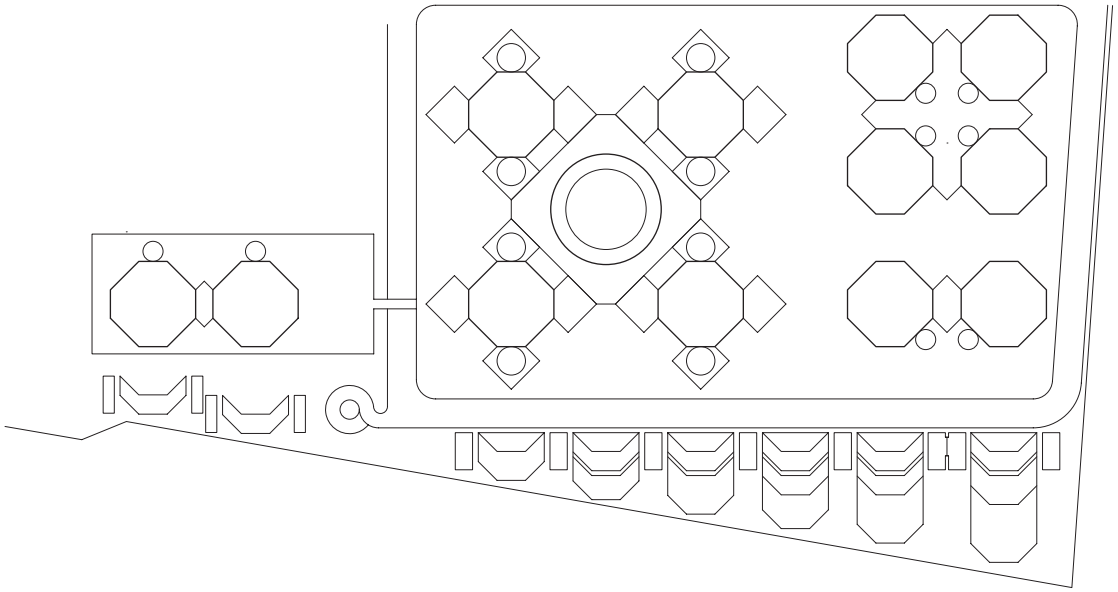
3.3.3 The Renaissance Center

Urban designs feature prominently in Portman’s corpus, with the earliest prototypes emerging from the mid-sixties to the mid-eighties. During this period, three of Portman’s urban projects were constructed in the United States, each demonstrating his evolving ideas for organizing cities. These mixed-use, urban scale projects are in: a) Atlanta, GA; b) San Francisco, CA; and c) Detroit, MI. The projects are diverse in terms of their process, context, and forms. In Atlanta, Peachtree Center is a living experiment in the existing downtown fabric, where Portman modeled and modified his urban interventions literally building by building and block by block – an ongoing project for over fifty years. In San Francisco, Embarcadero Center consists of five blocks integrated within a master plan orchestrated all at once that was relatively immediate in its execution and supported in its adjacency to the downtown business district. In Detroit, the Renaissance

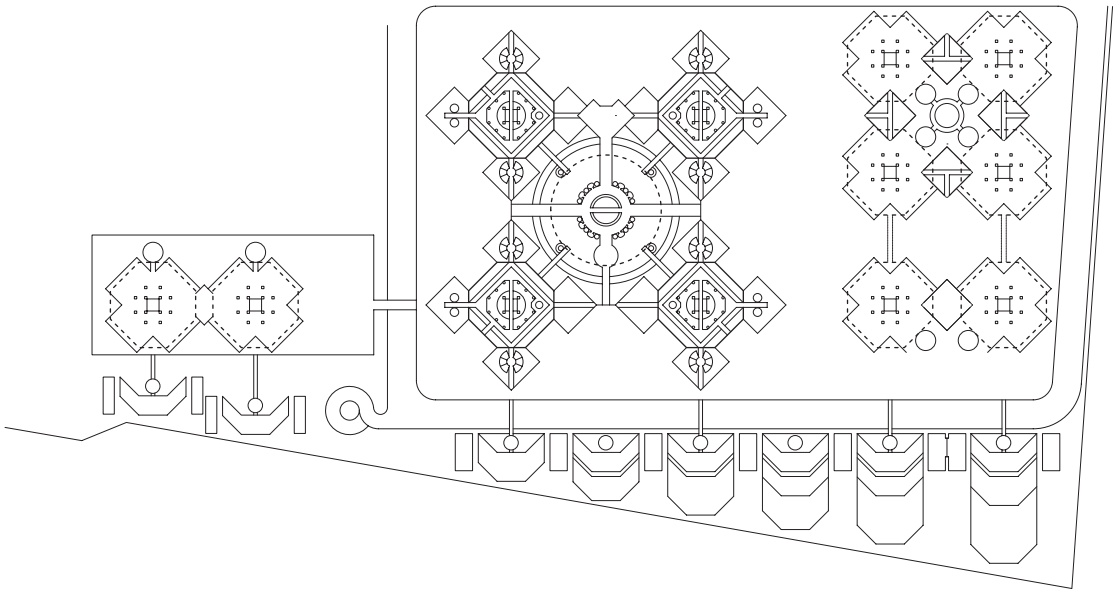
Center was both the riskiest and the most expressive of Portman's evolving concept for the "coordinate unit" at the scale of the city. With this concept, Portman emphasized coordination as a comprehensive design act, with an ambition to integrate buildings as more interdependent groupings of spaces. Within this conception, the design goal is to achieve a "single intricate organism," a "cellular pattern whose scale is the distance an individual will walk before he thinks of wheels," and a "total environment in which practically all of a person's needs are met" (Portman and Barnett, 1976: 129-131).

Due to its significance in describing Portman's urban ideals at a comprehensive scale, the Renaissance Center (Figure 3.39; Figure 3.40) will be the focus of the corpus on urban organization in this research. The project's iconic, futuristic character was celebrated on the cover of the *Transformations in Modern Architecture* catalog for an exhibition of the same name at the Museum of Modern Art (Drexler, 1979). The design is boisterous and isolated, a commission initiated by Henry Ford to upgrade the motor city where Portman was hired to take on the cleared, 32-acre site and asked to "bring about the rebirth of downtown Detroit." The project was intended to jumpstart a new pattern in the city, one that would eventually build "connections from the center growing back to meet and intertwine with the rest of downtown" (Portman and Barnett, 1976: 50). The design created in response to these ambitions features a cluster of five towers as its main focal point, with clusters of similar mid-rise towers book-ending either side of the central composition, and a large base beneath the entire assembly, sited with a series of articulations facing the waterfront.

The underlying geometric organization developed for the urban scale is analyzed in a series of diagrams shown in Figure 3.41 to establish the coordinate unit as a compositional module used recursively in the arrangement of the entire project. The first



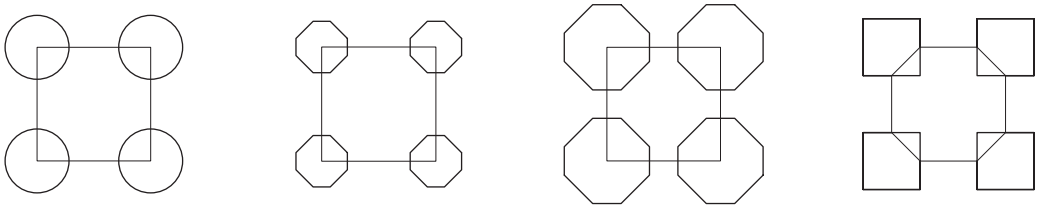
(a) site plan



(b) podium level

Figure 3.39 Plans of The Renaissance Center: (a) site plan; (b) podium level.

Figure 3.40 The Renaissance Center. Image © 1977 Alexandre Georges, The Detroit Renaissance Center Collection, courtesy The Portman Archives.



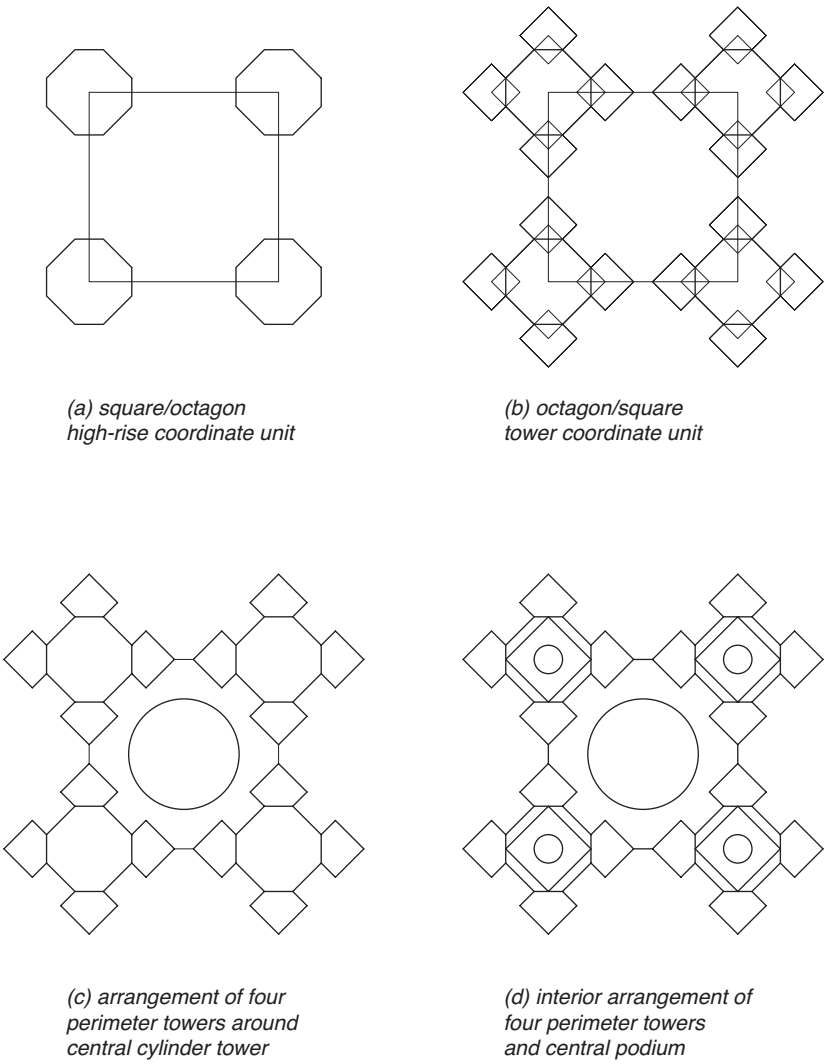
(a) square/circle *(b) square/octagon 1* *(c) square/octagon 2* *(d) octagon/square*

Figure 3.41 The Coordinate Unit: four variations in arrangement and scale.

diagram recalls the domestic coordinate unit of Entelechy I (Figure 3.41(a)), where the square organizes the distribution of circular figures throughout the design. Similarly, the diagrams developed in Figure 3.41(b) and (c) each describe variations on arranging four figures to define the four corners of a square organization. At Renaissance Center, the corners are celebrated with octagonal figures and the difference between these two diagrams is in the scale of these figures relative to the square that defines the overall composition. These two diagrams map to the organization of the high-rise towers in the central cluster (Figure 3.41(b)) and the mid-rise towers in the side clusters (Figure 3.41(c)). The smaller arrangements of pairs of mid-rise towers are simply a subdivision of the module in Figure 3.41(c). The final diagram, shown in Figure 3.41(d), reverses the relationship between the square organization and the octagonal figures so that the corners are articulated by square figures arranged on four sides of the central octagon. This characterizes the recursive relationship between the individual octagons in Figure 3.41(b) and the individual high-rise towers which are further articulated as individual coordinate units at the scale of the building.

To follow the development of these units in further detail, additional studies on the high-rise and mid-rise tower organization are given in Figure 3.42 and Figure 3.43. Starting

from the initial high-rise coordinate unit shown in Figure 3.42(a), Figure 3.42(b) describes the layering of the high-rise tower unit (Figure 3.41(d)) on the overall cluster. When this plan diagram is cleaned up and completed with the addition of the central cylindrical tower, as illustrated in Figure 3.42(c), the geometric arrangement of the five tower cluster of the Renaissance Center (Figure 3.39(a)) is achieved. The final diagram of the high-rise configuration, shown in Figure 3.42(d), illustrates how the geometric organization



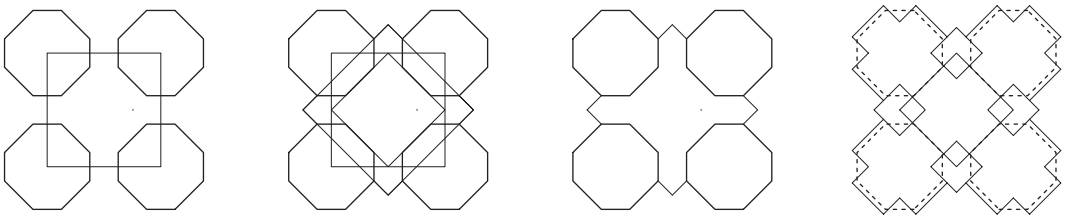
(a) square/octagon high-rise coordinate unit

(b) octagon/square tower coordinate unit

(c) arrangement of four perimeter towers around central cylinder tower

(d) interior arrangement of four perimeter towers and central podium

Figure 3.42 The Renaissance Center: coordinate unit development for high-rise tower organization.



(a) square/octagon low-rise coordinate unit

(b) shared podium organization

(c) arrangement of four towers around podium

(d) interior arrangement at shared podium

Figure 3.43 The Renaissance Center: coordinate unit development for low-rise tower organization.

continues to develop on the interior podium level of the central tower arrangement to map to the plan of Renaissance Center shown in Figure 3.39(b).

In addition, the development of the four mid-rise towers and their shared podium is studied in the diagrams of Figure 3.43. The square/octagon organization for this cluster is given in Figure 3.43(a). Building on this construct, Figure 3.43(b) analyzes the geometry of the central shared podium, defined by a pair of rotated squares at two different scales. The larger square maps to the outer definition of the podium as shown in Figure 3.43(c), while the smaller square maps to the interior arrangement depicted in Figure 3.43(d). Together the last two plan diagrams relate to the mid-rise arrangement in the site plan (Figure 3.39(a)) and podium level plan (Figure 3.39(b)), respectively. Once the mid-rise cluster is understood, the smaller pairs of towers can be read as transformations and subdivisions of this organization. The coordinate unit at the urban scale is then understood as a recursive system generating self-similar structures intended to relate to one another in a more comprehensive pattern of relations initiated in the forms themselves. Their formal coordination implies how the pattern could continue in future growth, suggesting a larger restructuring of the city that would respond to this organization.

3.3.4 Entelechy II

The final project of the corpus focuses on residential design to examine the evolution of Portman's language at the domestic scale from Entelechy I (1964) to Entelechy II (1986, Sea Island, GA, USA). The second house, a 22,000 square foot retreat built to expand and contract for personal visits and entire family gatherings, has been described as Portman's "autobiography" (Hagberg, 2009). Conceived as a self-contained "island on an island," the house is a monumental family retreat, complete with a series of art gardens. The beachfront site of the retreat inspired its conceptual characterization as a giant beach umbrella with a "house lying underneath." In his own essay on the "home museum" Portman describes his adoption of the Aristotelian concept of *entelechy* for which the two homes are named, and the second house is therefore considered his closest physical realization to that conception in its pursuit to "probe the meaning of architecture as a living organism" (1997: 9). Representing over twenty years of that inquiry, the house provides a personal lens into Portman's language, process, and architectural principles.

At first glance, Entelechy II is difficult to decipher with its multiple pavilions, parts, and pieces, together assembling a surprising composition of exterior and interior spaces. What unifies the sprawling oasis is its dominant square roof (Figure 3.44; Figure 3.45), the "umbrella" that shelters four interconnected pavilions and covers a shared central court between them (Figure 3.46). The house is a variation on a simple courtyard house with a monumental central court. Portman's "inner court" is an exterior space sheltered by side gallery walls perpendicular to the beachfront and pavilions of interior spaces that span the other direction in parallel, all unified by the umbrella roof. The continuity of the ground plane, echoing the open-air roof, and the exaggerated vertical columns support the relationship between both exterior and interior spaces. More private interior spaces are

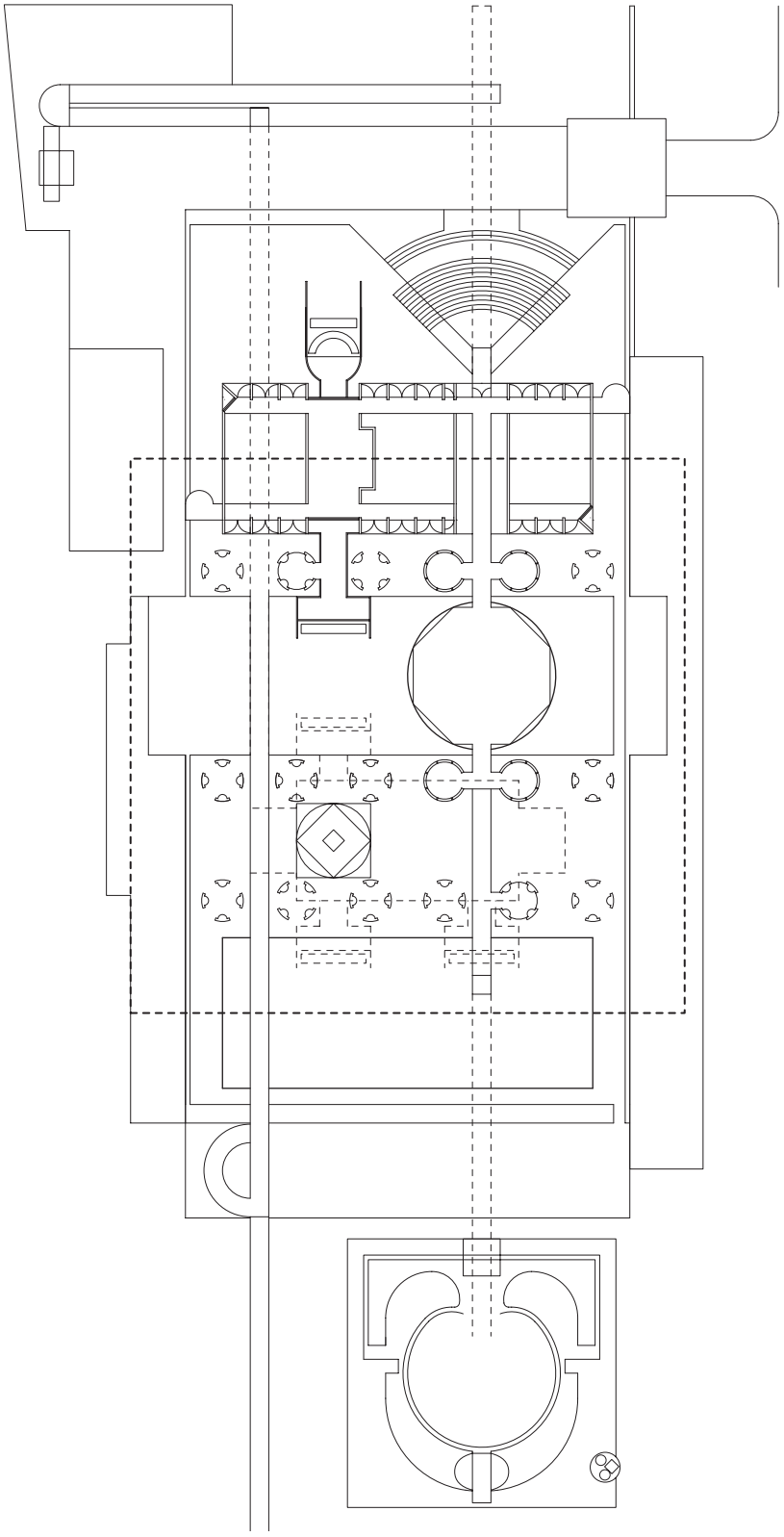


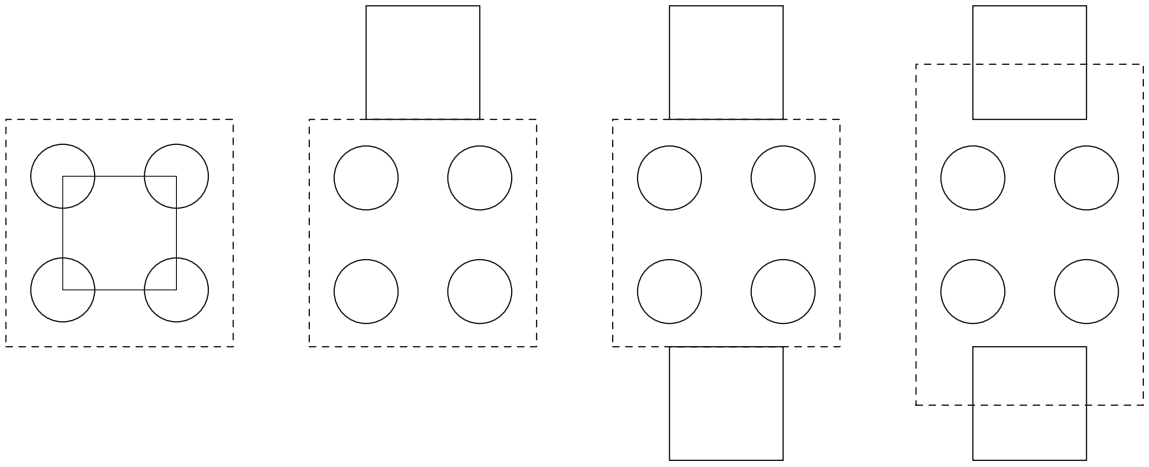
Figure 3.44 Piano nobile plan of Entelechy II (with overall site plan below).

Figure 3.45 Entelechy II: exterior view from the entry drive. Image © 1995 Michael Portman, The Entelechy II Collection, courtesy The Portman Archives.

Figure 3.46 Entelechy II: exterior view from the central court. Image © 1989 Michael Portman, The Entelechy II Collection, courtesy The Portman Archives.

provided in three rectilinear living/sleeping pavilions and one living/dining pavilion for secondary activities away from the main court, the yard, and the beachfront beyond.

The formal organization of the house expands on the spatial concepts of Entelechy I, where the figural hollow columns establish a sense of order. The diagrams in Figure 3.47 analyze this relationship considering one module of the domestic coordinate unit from the original house design (Figure 3.47(a), which also includes the dashed roof outline above to relate more directly to the umbrella concept of Entelechy II) to study how it transforms from the Atlanta house to the Sea Island house. The first transformation separates the codependent, overlapping relation between the figures of the minor spaces and the field of the major spaces (Figure 3.47(b)). The figures remain related to the roof, but the field spaces are transformed as independent pavilions removed from the central exterior court. The second transformation reflects the pavilion to double the interior space



(a) Entelechy I_ coordinate unit w/ roof outline above

(b) separate_ major + minor spaces

(c) reflect_ double major spaces

(d) extend_ roof to unify exterior/interior

Figure 3.47 From Entelechy I to Entelechy II: precedent, separation, reflection, and extension diagrams.

and create a perimeter boundary as described in the diagram of Figure 3.47(c). Finally, a third transformation extends the roof to hover over the boundary pavilions, unifying the interior and exterior composition as shown in Figure 3.47(d). These simplified diagrams are elaborated in the studies of Figure 3.48 - Figure 3.51 to focus on analyzing the larger aggregation of interior and exterior spaces in the design of Entelechy II.

The geometry of the beach house is organized primarily around the square roof, which functions as a perforated shading device and ordering element of the structure. The

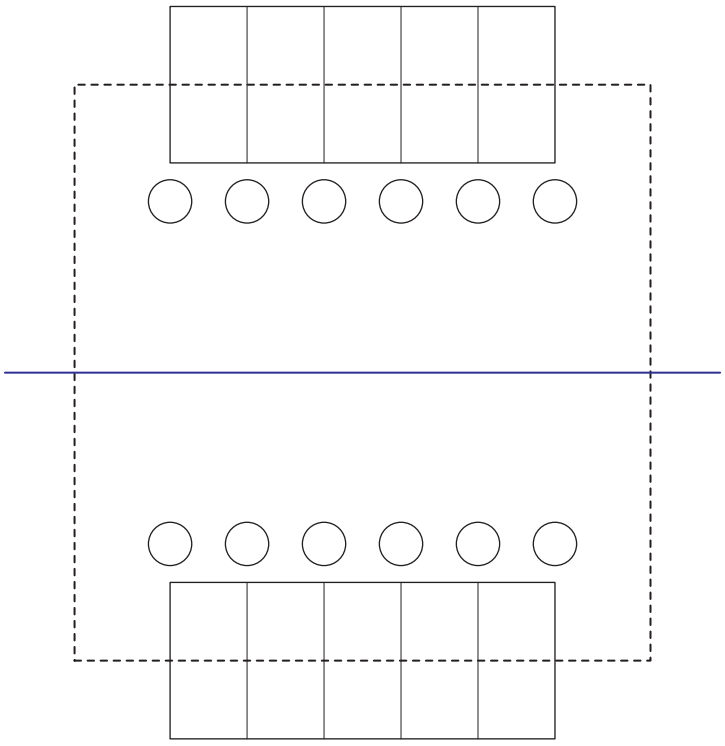


Figure 3.48 Entelechy II: plan diagram describing the primary axis of bilateral symmetry that relates the living/sleeping pavilions and figural rows of six columns to the square roof above.

plan diagram of Figure 3.48 emphasizes the primary axis of bilateral symmetry that relates the roof's geometry to the outmost bound of living/sleeping pavilions and related figural rows of columns that define the perimeters of the primary orientation, parallel to the beachfront. This diagram can be considered a transformed version of the base module described in Figure 3.47(d). Building on the diagram of Figure 3.48, Figure 3.49 describes the addition of the third row of figural columns along a secondary axis of bilateral symmetry that relates the rows of columns and subsequently divides the courtyard space. The result

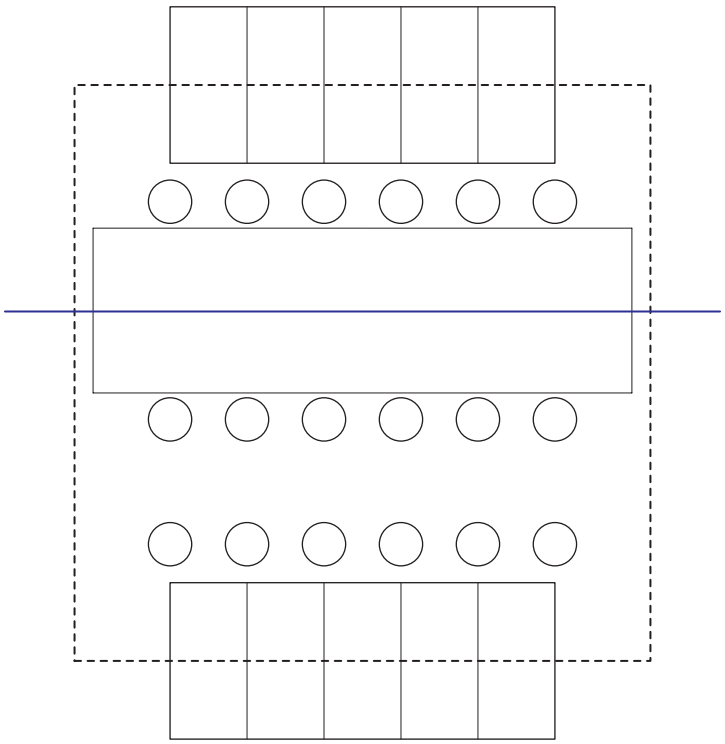


Figure 3.49 Entelechy II: plan diagram describing the secondary axis of bilateral symmetry that relates a third figural row of six columns that line the pool of water that divides the central courtyard space.

is two court areas: one defined by the calming reflection pool, and a second defined by the remaining field of occupiable space for gathering within the sheltered exterior court.

The asymmetrical circulation axes of the project run perpendicular to the organizing axes as shown in the diagrams of Figure 3.50 and Figure 3.51. The primary entry axis of circulation is shown in Figure 3.50. Starting from the monumental entry stair at the top of the figure, this axis initiates movement across the upper level of the piano

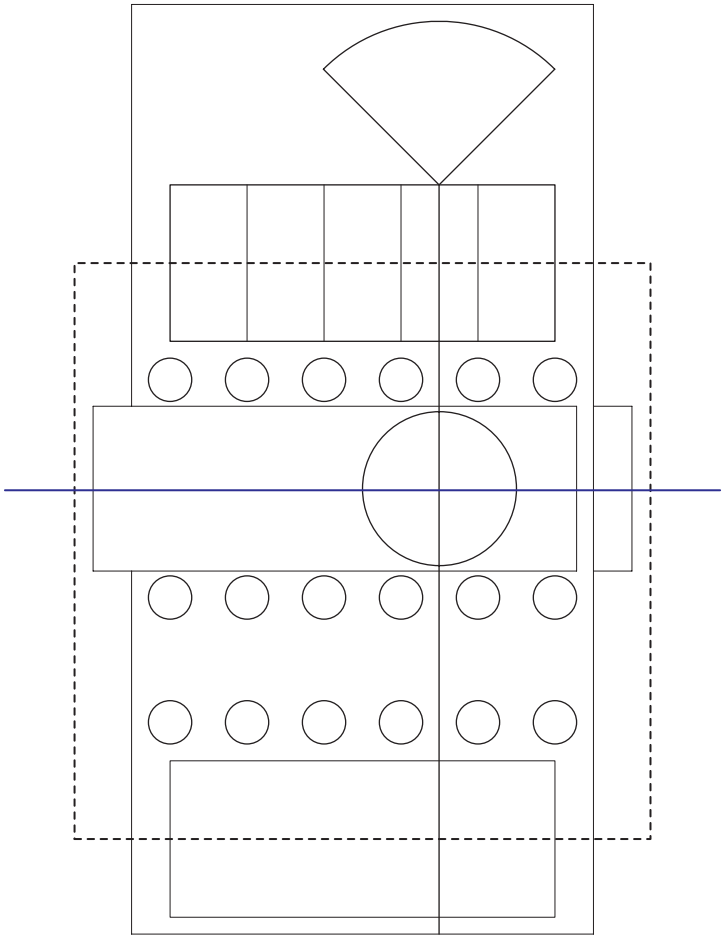


Figure 3.50 Entelechy II: plan diagram describing the asymmetrical entry axis that pulls a path of circulation from the curvilinear stair at the entry drive (top of the figure) to the backyard and beach beyond (bottom of the figure). At the intersection of the entry and pool axes, a third curvilinear living/dining pavilion is located.

nobile from arrival at the main drive to the roof of the one-story edge pavilion overlooking the backyard and beachfront. The axis is continued formally to extend its organization out to the backyard pool as shown in the dashed overhead lines of the plan (Figure 3.44). At the intersection of this axis and the reflecting pool, the third pavilion - a curvilinear, two-story living/dining space - is located. To complete the arrangement of the main living spaces, Figure 3.51 shows the secondary circulation axis and its relation to the fourth

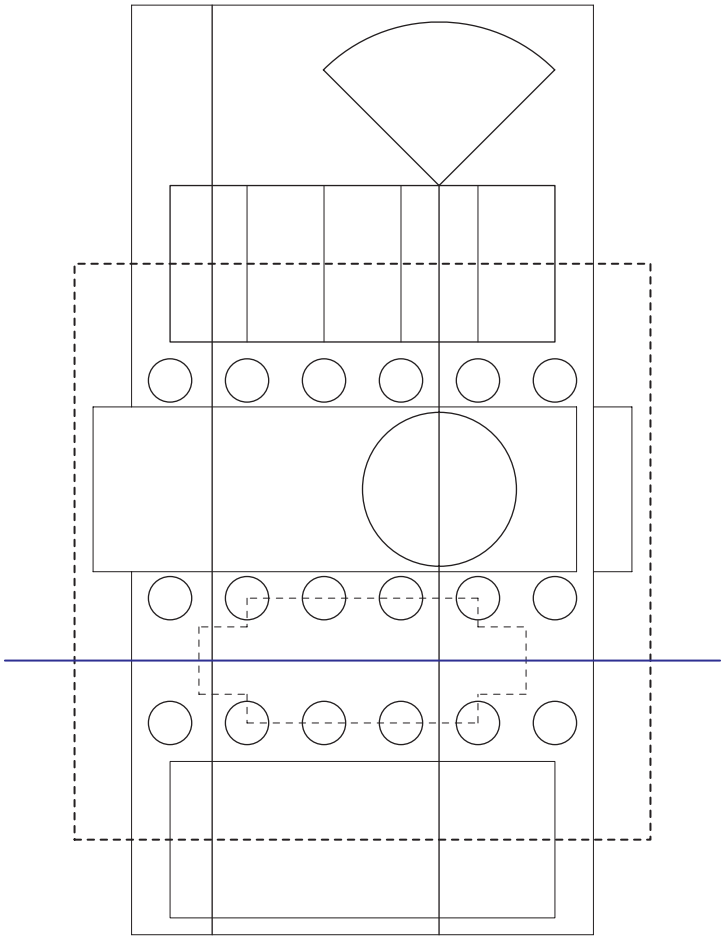


Figure 3.51 Entelechy II: plan diagram describing the tertiary layer of bilateral symmetry that relates the fourth living/sleeping pavilion (dashed above) and the secondary axis of circulation that connects that pavilion from the entry drive (top of the figure) to the backyard and beach beyond (bottom of the figure).

interior living/sleeping pavilion, Portman's private apartment dashed above the central court on the third level. This circulation axis is initiated at a long step-ramp lining the driveway to ascend to the third level. It then continues out beyond the boundary of the roof to a curvilinear staircase at the backyard that connects back to the ground level and an on-axis footpath to the beach. The remaining spaces of the design illustrated in the piano nobile plan (Figure 3.44) – the gallery side walls, swimming pools, garage, etc. - all respond to the geometries, axes, and resulting forms described in these diagrams to organize the beach house. The basis of this organization is a newly transformed domestic coordinate unit for residential design.

3.4 On Entelechy

The conception of Entelechy I as an implicit machine for Portman's architectural principles is initially described abstractly, succinctly, and without a unique name for the residence in *The Architect as Developer* (Portman and Barnett, 1976). However, by the time Portman designed his second house at the beach, over twenty years later, he had settled on a name for both houses that points to his larger ideals and ambitions: Entelechy.

The term originates in Aristotelian metaphysics, where ἐντελέχεια (entelecheia) describes a process of becoming from an intrinsic potential. By contextualizing the corpus presented here with an interpretation of *entelechy*, a philosophical counterpart to Portman's forms comes forward. This is offered to speculate on Portman's goal to understand architecture as a "living organism" (1997), read with particular attention to Emersonian, and ultimately, Wrightian ideals.

Portman discusses the name of the homes in an essay where he describes entelechy as "environment as substance … where potentiality, activity and actuality

become one." He further defines the term in reference to his ambition to "probe the meaning of architecture as a living organism." The concept is more directly explained,

> The name Entelechy symbolizes the endeavor to distinguish actuality from potentiality. All apparent phenomena are mere forms for a greater reality lying beneath (1997).

The text goes on with a succinct interpretation of entelechy from the *Encyclopedia Britannica* definition, where it is described as "that which realizes or makes actual what is otherwise merely potential." The definition includes an association with Aristotle's distinction in the hylomorphic model between matter (inherently possessing many potentials) and form (an actual, physical expression) and how this relates to distinguishing being (*ousia*) – the "soul" or "vital function" of the living organism. Following this definition, a concise statement on "architecture in its *idealized state*" is offered by Portman to reinforce his understanding of his homes as experiments in how to realize this ideal (1997). This realization is a transformation, a movement from a perfected conception in the imagination (a potential) to a formal reality in the built environment to be experienced and lived in (the actual). In Portman's conception, the goal of realizing potential considers form as a living organism, where the ideal is grasped for physically in an individual design expression and experientially through human use. Organism is considered not in terms of biology, but in formal and organizational structure, following Wright's Emersonian understanding of nature and individuality (see chapter 1).

Though these descriptions and related aspirations are given in a conceptual way, the terminology surrounding Aristotle's concept of entelechy is notoriously unresolved in scholarship, so it follows that the question of how Portman understood and interpreted this

term is equally unresolved. His statements on the term are curious in their brevity given the philosophical debate on the meaning of entelechy, but at the same time, Portman was not an Aristotelian scholar. Still, the definitions do include the three key terms of inquiry: potentiality (δύναμις *dunamis*), activity (ένέργεια *energeia*), and actuality (έντελέχεια *entelecheia*), suggesting that Portman had read enough to construct his own meaning related to design separate from the larger philosophical debate.

The primary source for understanding the Aristotelian terminology is in the philosopher's theory on motion in Book Θ of the *Metaphysics*, where all three terms are discussed. Aristotle is clear in his explanation that *energeia* and *entelecheia* are to be understood as related terms,

> The term "actuality" *(ένέργεια energeia)*, with its implication of "complete reality" (έντελέχεια *entelecheia*), has been extended from motions, to which it properly belongs, to other things; for it is agreed that actuality *(ένέργεια energeia)* is properly motion (Aristotle, *Metaphysics*, Book Θ, 1047a, 30).

While the connection between the terms is acknowledged, what is less clear is how the two terms support each other in their relationship to potentiality (*dunamis*) to bring a unique understanding to motion in things. Focusing exclusively on activity (*energeia)* and potentiality *(dunamis)*, Aristotle offers this explanation,

> "Actuality" *(ένέργεια energeia)* means the presence of the thing, not in the sense which we mean by "potentially" (δύναμις *dunamis*). We say that a thing is present potentially (δύναμις *dunamis*) as Hermes is present in the wood, or the half-line in the whole, because it can be separated from it; and as we call even a man who is not studying "a scholar" if he is capable of studying. That which is present in the

> opposite sense to this is present actually. What we mean can be plainly seen in the particular cases by induction; we need not seek a definition for every term, but must comprehend the analogy: that as that which is actually building is to that which is capable of building, so is that which is awake to that which is asleep; and that which is seeing to that which has the eyes shut, but has the power of sight; and that which is differentiated out of matter to the matter; and the finished article to the raw material. Let actuality *(ἐνέργεια energeia)* be defined by one member of this antithesis, and the potential (δύναμις *dunamis*) by the other.
>
> But things are not all said to exist actually in the same sense, but only by analogy—as A is in B or to B, so is C in or to D; for the relation is either that of motion to potentiality (δύναμις *dunamis*), or that of substance (ούσία *ousia*) to some particular matter (Aristotle, *Metaphysics*, Book Θ, 1048a, 31-1048b, 1-8).

The analogies Aristotle uses as examples to emphasize his interest in not requiring explicit definitions but "only by analogy" are particularly instructive in trying to piece the meaning of entelechy together. Following this advice, *dunamis* or potentiality is the possibility of Hermes in a block of wood or a half-line in the whole – a partial relationship capable of existing because of the matter in consideration. A material possibility is an embedded potential that can be "separated out," distinguished, or recognized and developed to create something else that is an actual, physical form. *Energeia* or actuality is the existence of the wood statue of Hermes or the half-line distinguished from the whole, but this is only a first level of the meaning of *energeia*. The passage goes on to establish *energeia* and *dunamis* as opposites and to specifically characterize two types of *energeia*: one as movement to *dunamis* and the other as *ousia* (substance, being, or thinghood) to matter.

Building on these analogies, *entelecheia* is compared to *energeia* to distinguish the action and the end,

> For the activity is the end, and the actuality *(ἐνέργεια energeia)* is the activity; hence the term "actuality"*(ἐνέργεια energeia)* is derived from "activity," and tends to have the meaning of "complete reality" (ἐντελέχεια *entelecheia*) (Aristotle, *Metaphysics*, Book Θ, 1050a, 22).

In this sense, *energeia* is both the action and the end, but it points to a complete reality, a higher-level realization found in *entelecheia*. Thus, entelechy is the “greater reality lying beneath” that Portman speaks of (1997). Returning to the analogies, Hermes and the half-line are actual forms, but they perpetuate a potential reality that extends beyond their current forms – and this can be understood as entelechy, their complete reality. The same is true in the analogy of building as to that which is capable of building, connecting the idea to architectural form.

3.5 Discussion

The corpus presented here emphasizes Portman’s organizational approach to design across scales, based on a developer-driven analysis of efficiency, paired with experimentation that exceeds, inverts, or breaks conventions, leading to results that are predictable and unexpected. The pragmatic, commercial basis for this design strategy is a clear driver of the forms themselves, but equally interesting is Portman’s focus on design principles that could guide his practice and be carried out by others to develop a family of signature products. These principles define a language that is recognizable, but malleable and adaptable – so that it can be appropriated to the unique conditions of a design context. This structure allows for the coordination of large-scale projects to be manageable with a

whole office of designers working to conceptualize designs, develop them, and oversee their construction in detail. Each designer is effectively trained to work within the logic of this language, with freedom to transform designs and expand the system as appropriate to the specificities of a project. The result is an approach to design practice that is equally interested in accountability, automation, and aesthetics.

The details of how to construct this argument are crucial – and following Portman's forms visualizes the concern for design process and principles of organization pursued in the designs, yielding repetition, transformation, and variation in the corpus. It is this expressiveness that drives paradoxical interpretations of the work, and Portman describes these principles as implicit to the organization of Entelechy I.

To hypothesize the house as system, it can be compared to Le Corbusier's Maison Dom-Ino to provoke its consideration within twentieth century architectural discourse. Corbusier's project laid the groundwork for his "Five Points Toward a New Architecture" of 1926 that were fully embodied in the Villa Savoye. The Corbusian housing system promotes combinatorial variety by establishing a structural uniformity that is separate from the interior layouts and the façade, allowing for tremendous design freedom. The name for this system, Dom-Ino, comes from the clever combination of an idea that the design is structured like a game of dominoes, allowing the modules to be lined up in multiple configurations. Equally clever, the term is a hyphenation of abbreviations of the Latin *domus* as "dom" and innovation as "ino". In the same way, the name Portm-Ino is proposed to establish the 1964 experiment at Entelechy I as a systematic effort by Portman, or "Portm," to be innovative, or "ino," in defining a set of flexible design principles. This juxtaposition aims to get to the heart of Portman's formal language by mapping it against the familiarity of Corbusier's model and framing it with a similar characteristic potential.

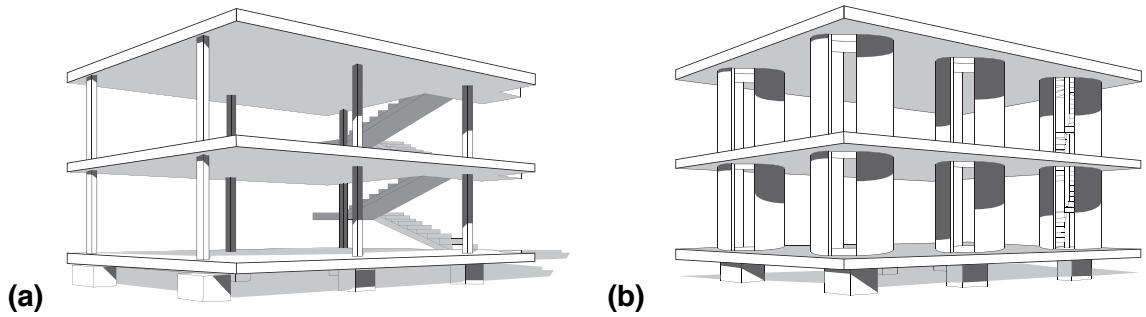


Figure 3.52 Domestic Systems of Le Corbusier and Portman: (a) Dom-Ino; (b) Portm-Ino.

And whereas the Dom-Ino can be considered an emblem of modernism, the Portm-Ino is proposed as an emblem of postmodern reinvention (Figure 3.52).

Framed comparatively, the Dom-Ino and Portm-Ino systems immediately offer an interesting contrast. Corbusier's five points – the pilotis, the free ground plan, the free façade, the horizontal window, and the roof garden (1926) – are reinvented in Portm-Inoes. Where the pilotis of the Dom-Ino minimize structure, the exploded columns of the Portm-Ino foreground structure as space to define a secondary module. Both Dom-Ino and Portm-Ino celebrate a notion of freedom in the ground plan, but in the Portm-Ino the slab is porous so that the unrestrained interior condition is connected on multiple floors and other functions, like staircases, can be regulated within these repeating punctures. Also, in Dom-Ino and Portm-Ino, a free façade is possible as the consistency of the structure allows this option. However, the Portm-Ino integrates the façade and the exploded column to hybridize structure, space, and enclosure – a move that challenges the definition of interior and exterior. The horizontal window of the Dom-Ino, which democratizes light across the interior is replaced by the vertical space and skylight in the Portm-Ino to infuse natural light into the depths of the interior volume. And, lastly, the roof garden of the Dom-Ino becomes an interior water garden in the Portm-Ino. These five

points, postulated in the Dom-Ino and revisited constructively in the Portm-Ino, utilize specific features and elements to represent architectural principles that can be thought to characterize the modern and the postmodern, respectively.

This is a provocative hypothesis, but how can this proposal get beyond the vignette to address design principles that translate from the Portm-Ino to a larger corpus, specifically the one presented in this chapter? More precisely, is there a way to unravel these principles not just as a residential system, but as an organizational system applicable from the scale of a room to a group of buildings? Another way to consider principles – and construct a more precise visual narrative - is to formalize them as rules, offering a radically different take on design principles. A rule-based approach allows for the question of an organizational system in Portman's corpus to be rigorously formalized and demonstrated in productive results. This method of critical, formal analysis and synthesis is pursued in the shape grammar discourse, providing a visual and generative approach to a corpus of designs – one that can engage the notion of coordinating form to bring new understanding to Portman's work.

3.6 Summary

A selected corpus of Portman's projects was presented and analyzed. The corpus began with the 1964 Entelechy I (Portman House) to establish the house as a key project defining the idea of coordination as an architectural concept. From the house, a secondary corpus including the Midnight Sun Restaurant (1968), a series of the Atria Hotels (1967-1985), and the Renaissance Center (1975) were presented and decomposed to analyze the formal moves and relations driving their spatial composition. All of these projects, representing interior, hotel, and urban designs, appeared in *The Architect as Developer*

(Portman and Barnett, 1976), reiterating their value to Portman's thesis on coordination as the architects' primary formal task at all scales of design. Finally, Portman's beach residence, Entelechy II (1986), was presented and analyzed to illustrate the evolution of the domestic coordinate unit from the first house to the second.

The questions of Entelechy I as a generative machine as well as of the relationship between the house and the rest of this corpus are compelling, provoking another effort to engage the paradox of Portman's forms. The background and visual analysis here are offered as a start to this discussion, along with the proposal of the Portm-Ino as a scaffold for understanding Entelechy I as a postmodern housing system. The project now is to develop this vignette with a rule-based methodology that can establish a new theory on Portman's architecture.

CHAPTER 4. THE ENTELECHY GRAMMAR

To explore the potential of Entelechy I as a housing system, a shape grammar is presented here that generates the original design of the house and a series of variations, called Portm-Inoes to build on the provocation and analyses of the previous chapter. The Entelechy grammar is a software implemented in *Shape Machine for Rhino* that encodes a set of visual algorithms crafted entirely on the frontend through straightforward, two-dimensional computer-aided drafting of shape rules. These rules are entirely interpretive – Portman never explained every step in designing the house, nor did he explicitly describe how he saw it as an organization guiding his design principles. In this light, the proof and value this interpretation offers is in critically testing the possibility of the house as an artifact that articulates a design philosophy in its form. In effect, the implementation is a thesis on how the house can be read compositionally, constructively, and computationally to broaden our understanding of Portman's specific approach.

4.1 Introduction

The shape grammar formalism is employed in this research for its explanatory value[75], achieved with visual production systems specified with shapes and shape rules (Gips and Stiny, 1980; Stiny, 1980a; 2006; Knight and Stiny, 2001).[76] The uniqueness of the formalism and the descriptions it provides are that they are visually and spatially defined – and in this way, they thrive on the ambiguity, possibility, and multiplicity of

[75] The shape grammar formalism focuses on questions of how to create good designs (Stiny and Gips, 1972), where designs come from (Stiny, 1980a), and how computers can aid humans in design processes (Knight and Stiny, 2001).

[76] Shape grammars are inspired by Chomsky's phrase structure grammars (1957) and were originally introduced to formalize generative specifications for languages of designs in painting and sculpture. Stiny and Gips, 1972.

interpretations characteristic to shapes as well as to design activity. A key argument of the discourse is that computing with shapes in this way is intuitive, perceptual, and recursive, providing a computational lens that can approximate the creative and critical processes designers use to develop drawings, models, mock-ups, and more in an iterative sequence en route to the explicit specification of precise, built structures (Stiny, 2006; Knight and Stiny, 2015). The tension in a design process – between the imprecise goal to produce a new, unknown form in a creative process of discovery and the various requirements that constrain that form to what a designer already knows or observes in terms of context, structure, use, material, space, and other systems – makes the strategic use of media a subject of increasing importance, especially today when a proliferation of computational techniques and technologies are available. These methods provide a potential feedback loop for reconsidering architectural theory, history, and criticism, too – which is how they are applied here to reconsider Portman's work starting from a rule-based interpretation of Entelechy I.[77,78]

[77] The paradigmatic example is the first architectural shape grammar on Palladian villa plans (Stiny and Mitchell, 1978). In its emphasis on the geometry and symmetrical arrangement of Palladian villa plans as crucial to their understanding, the Palladian grammar reinforces Wittkower's (1949) recognition of a geometrical system evident in a corpus of eleven Palladian villas that demonstrate the theoretical principle of bilateral symmetry – often discussed as a Renaissance ideal, but seldom practiced beyond the planar arrangement of the façade. Wittkower illustrates his formal analysis of these villas to foreground their geometric organization in plan and proposes a twelfth pattern identifying their underlying tartan composition as a fundamental design principle. The Palladian grammar further studies these spatial relationships and their development in individual designs to propose a formal theory for generating Palladian villa plans with shape rules. Designs produced by the shape grammar include both actual designs from Palladio's corpus and new interpretations that conjecture artificial design solutions that Palladio never realized. The grammar thus concisely and explicitly encodes an interpretation of "how to put together Palladian villa plans," offering this knowledge in an algorithmic format specified by visual shape rules (Mitchell, 1990: 179-181).

[78] For example, Flemming's shape grammar for Terragni's Casa Giuliani Frigerio (1981) is a visual, explanatory response to Eisenman's conclusion that the formal principles of the building are difficult, and even hopeless, to precisely assess. And, Koning and Eizenberg (1981) argue that their grammar for Frank Lloyd Wright's prairie style houses sharpens our understanding of the basic composition of the designs, noting that this has been a challenging subject for historians who have struggled to adequately describe the balance inherent to the prairie style, notably Hitchcock, who described it as occult. In addition, Economou (2018) contends that the obscure nature of the six

In developing a computational approach to architectural theory, shape grammars focus on shapes and spatial relations, formalized in visual computations to achieve two and three-dimensional designs defining languages. The specification of a shape grammar thus results in the generation of two things: a theory on a language of designs described in shape rules and a set of designs produced by the rules. Shape rules are specified with a matching condition on their left-hand side (*LHS*) and a replacement for that condition on their right-hand side (*RHS*). Shape rules can be thought of as visual if/then statements to encode a query and replacement process specified by shapes.

Shape computations are further structured in shape algebras defined for basic elements – points, lines, planes and solids – specifying the space, operators, and transformations under which shape rules apply. The operations of sum, +, and difference, -, allow basic elements to combine or subtract from one another. Transformations, *t*, translate, rotate, reflect, and scale basic elements in a Euclidean space. Most importantly, the part relation, $\leq$*,* defines how basic elements are contained in other basic elements in terms of identity for points and in terms of embedding for lines, planes, and solids (Stiny, 2006).[79]

Vitruvian principles of design and their relation to the three prerequisites of design can be understood through the shape grammar discourse.

[79] Formally, a shape rule in the form

$A \rightarrow B$

is applied to a shape, C , representing a specific design context where the rule is applied. The rule can be applied when a match occurs as described by

$t(A) \leq C$

when a transformation, *t(A)*, is found within the shape *C*, so that by the embedding relation, $\leq$, the shape on the *LHS* of the rule, *A*, is recognized as a part of the shape C that the rule applies to. Once this match is found, the shape rule can be applied. Application means that the RHS shape, B, replaces the *LHS* shape, *A*, in the context of the design *C*, following the operation

$(C - t(A)) + t(B)$

so that the part defined by the transformation, *t(A)*, is subtracted from the shape *C*. Then, it is replaced with the transformation, *t(B)*. When a rule is applied to the shape, *C*, the results of this replacement produce the new shape *C'*. The new shape, *C'*, is redescribed entirely by its maximal

The Entelechy grammar is described by shape rules that interpret the potential of Entelechy I as a generator for a broader domestic language, characterized by Portm-Ino designs. Significantly, the shape rules and designs of the Entelechy grammar are all implemented in *Shape Machine for Rhino*.[80] The implementation allows for the shape grammar to be automated[81], so that the shape rules are rigorously defined, tested, and verified in their productive outcomes.

The shape rules of the Entelechy grammar are organized in three stages to correspond to an incremental architectural design process. The stages are: Stage 1: Framework; Stage 2: Configuration; and Stage 3: Architectonics. The first stage,

---

representation (Stiny, 1980; 1986; Krishnamurti, 1981), which fuses the composition together anew to enable the process to continue recursively with the same shape rule or new ones, as desired. This means that subshapes or parts can be recognized in a shape that were never added in any previous shape rule, enabling surprises or emergence to occur (Knight, 2003; Stiny, 2006). This unique potentiality of shape rules redefines the notion of a rule and what it means to calculate – and makes the argument for the value of computing with shapes in art and design.

[80] The work here aims to reengage the possibility of shape computation in architecture by utilizing a new medium for programming with shapes as the primary method of inquiry. The technology, *Shape Machine for Rhino*, addresses a fundamental challenge in shape grammars since their inception: the difficulty of implementing a general shape computer (that calculates with visual code described in a maximal, discontinuous shape vocabulary of points, lines, planes, and solids) within the general symbolic computers we use today (that calculate with binary code described in a minimal, discrete symbolic vocabulary of 0 and 1). While many shape grammar interpreters have been proposed (over 60 to date, nearly half of which are general-purpose), none of them have provided a general solution for key concepts that distinguish computations with shapes as outlined in the mathematics of shape grammar theory (Hong and Economou, forthcoming). The problems of subshape recognition, shape mapping replacement, and a visual interface where designers can compose specifications directly with geometry remain especially unresolved (Economou et al, 2019; Eloy et al, 2018; Stiny, 2006). *Shape Machine* directly addresses these issues by providing a technology for shape computations with two-dimensional lines and arcs under all Euclidean transformations, allowing designers to experiment with an alternative method for rule-based interpretation and design within this initial algebra and set of transformations.

[81] The process to automate a shape grammar in *Shape Machine* is straightforward in the sense that the entire activity occurs within the Rhino design environment. The current version of the plug-in is operated with five key components on the frontend: a) the viewport workspace for graphical definitions, preview displays of candidate matches for rule application, and the generation of a design; b) the standard toolbar for drawing shapes composed of lines and arcs to serve as inputs for the engine, all specified within a rule template utilized in the Rhino workspace; c) a custom toolbar that calls the functions of the engine as encoded for the transformations under which shape recognition and shape modification apply; d) the layers panel for assigning attributes to shapes; and e) the standard command line to communicate feedback from the engine and prompt user action or selection as required.

Framework, develops a modular system of major and minor gradations to provide a strategy for corresponding spaces in the domestic coordinate unit. The second stage, *Configuration*, develops the framework to reflect the conceptual organization of spaces in a design. The third and final stage, *Architectonics*, then delineates the architectural elements to develop the design following the conventions of an architectural plan.

A visual description of the shape rules for each stage will be explained step-by-step in the following sections to generate a 3 x 5 design that correlates to the original upper level plan of Entelechy I (Figure 3.4(a)). For clarity and simplicity, the design is represented as a single upper level floor plan. The upper level is chosen for two reasons: first, because it is a piano nobile that functions as the main entry in the overall design of the house; and second, because it provides a clearer understanding of the organization of the house in terms of spatial connection and volume than the lower level. The presentation of the specific rules that develop the upper level of Entelechy I is complemented by additional rules that are interpreted as possible expansions of the domestic system used to develop Portm-Inoes of varying size and single-family programs of use.[82] These additional rules are discussed and included in figures that depict the complete ruleset of each stage at the end of its corresponding section. The complete ruleset figures specify additional details on each rule, including: a) the rule number; b) the rule name, which offers a concise description of what the rule does; c) the transformation under which the rule applies; and d) the application mode for each shape rule.[83] Following

[82] It should be noted that these rules are designed to be applied line-by-line, sequentially, in the same order in which they are presented, so that the software can automatically generate plans, if desired.

[83] The application mode requires some further definition. A rule may be applied in two official modes in *Shape Machine*, one match at a time or in sums as described by the “apply all” specification. In the Entelechy grammar, these two modes are deployed in six possible ways to customize rule application for a desired design outcome. These six ways include: a) one at a time, defined in the

this setup, calculations specified in the Entelechy grammar are in the direct product algebras U_{12} x V_{12} to specify a design space of straight lines, arcs, and labelled lines in two-dimensions (Stiny, 2006).[84]

The starting point for the Entelechy grammar is an initial rule, *i*. The initial rule (Figure 4.1) establishes the parameters of the major module in the grammar, which adheres to the 16-foot by 16-foot dimension of Entelechy I. The initial shape consists of a single major module with three labels – two triangular and one circular. The two triangular labels, each distinguished by a separate layer as illustrated in the colors of the figure, allow for major grid growth in two directions in subsequent rules. The circular label orients the primary entry side of a design according to the representation in plan, which is always up in the grammar and the same in the presentation here for ease of comparing design variations. The application of this rule is implemented once per design variation to start the production process by generating a single major module.

i. initial shape: locating the front corner

Figure 4.1 Entelechy grammar - Initial rule to instantiate the first module of the major grid.

ruleset as *1x*; b) one at a time recursively for a limited range, defined in the ruleset to specify these limitations, for example *1x-3x*; c) one at a time recursively until the rule no longer applies, defined in the ruleset as *1x loop all*; d) in sums, defined in the ruleset as *apply all* to match the command in *Shape Machine*; e) apply all for a limited range, defined in the ruleset to specify these limitations, for example *apply all 1x-5x*; and f) without restrictions, defined in the ruleset as *free*, meaning the rule can be applied as many times as a match is found and the designer wants to implement it.

[84] This algebra corresponds to the current capabilities of *Shape Machine for Rhino*.

4.2 Stage 1: Framework

The first stage of the Entelechy grammar develops a tartan grid that sets the underlying compositional structure of the house, as characterized by major and minor modules that create a dual framework. This modularity is the underlying basis for coordination of major and minor spaces in the domestic coordinate unit. The development of this layered context is automated with five shape rules.

The process to define the modular framework starts with the definition of the major grid, which is produced with two shape rules in the grammar to specify a grid of *n* x *m* major modules. Rule 1, shown in Figure 4.2(a), allows for the modules to grow in one direction, *n*, by specifying a *LHS* that matches the initial shape produced with the initial rule and a *RHS* that adds a second major module. Along with this growth of the grid, the labels are reconfigured so that the label for growth in the *n* direction is moved to a location at the edge of the new grid module and a new label that will guide growth in a second direction, *m*, is added to the overall composition.

Figure 4.2 illustrates the application of rule 1 to generate a 3 x 1 major grid design. The first application of rule 1 starts with the design of Figure 4.2(b), the shape generated with the initial rule. When rule 1 is applied to this shape, a single match is found as depicted in Figure 4.2(c), where the red highlight shows the *LHS* match of the rule and the blue highlight is a preview for the *RHS* application of the rule.[85] When this first match is applied, a labeled 2 x 1 grid is produced. In the example here, we are designing for a 3 x 5 grid to generate the upper level of Entelechy I, so one more application of this rule is needed to

[85] This representational convention is intended to reflect the user experience in *Shape Machine for Rhino* and is utilized throughout the discussion of the shape rules to simulate interaction with the machine.

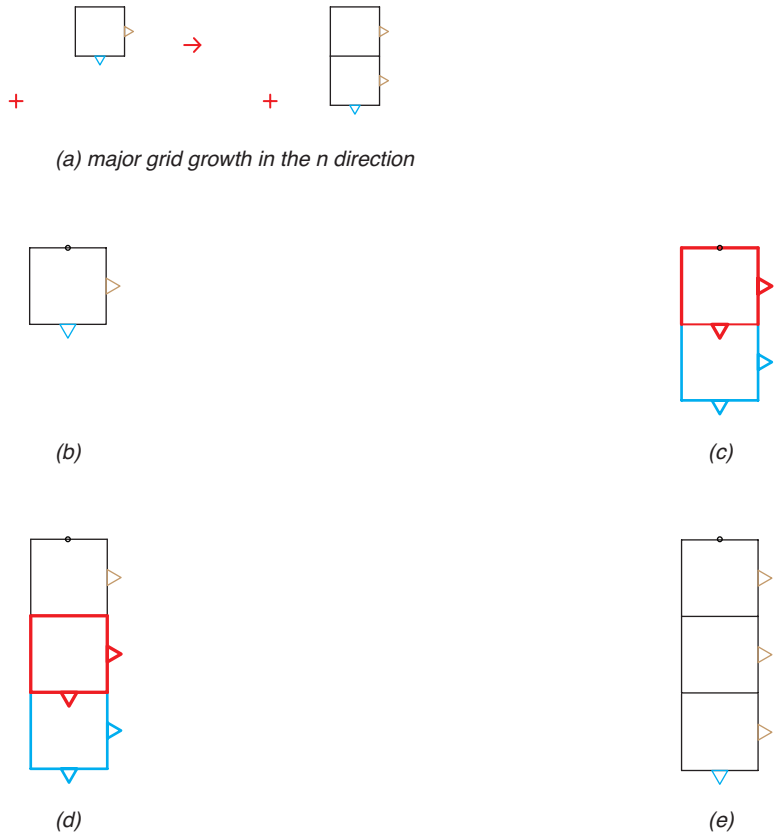


Figure 4.2 Entelechy grammar – Rule 1 to define major modules in the *n* direction: (a) rule; (b) initial shape; (c) rule application 01; (d) rule application 02; and (e) 3 x 1 major grid design.

produce an *n* of 3. This second application is achieved by applying the rule to the 2 x 1 grid as shown in Figure 4.2(d) to generate the labeled 3 x 1 grid of Figure 4.2(e).[86]

Once the *n* dimension is defined, the next step is to expand the major modules in the second direction, *m*, with rule 2 as shown in Figure 4.3(a). The *LHS* of this rule includes a single major module of the grid labeled with one triangular label that indicates the *m* direction. When this condition is matched, the *RHS* adds a second major module and

[86] One additional note on this rule that should be considered is that the Entelechy grammar is designed for variations within a range of domestically calibrated *n* x *m* grids. To take this into account, rule 1 is limited to a maximum of 3 applications to avoid exceeding an *n* of 4.

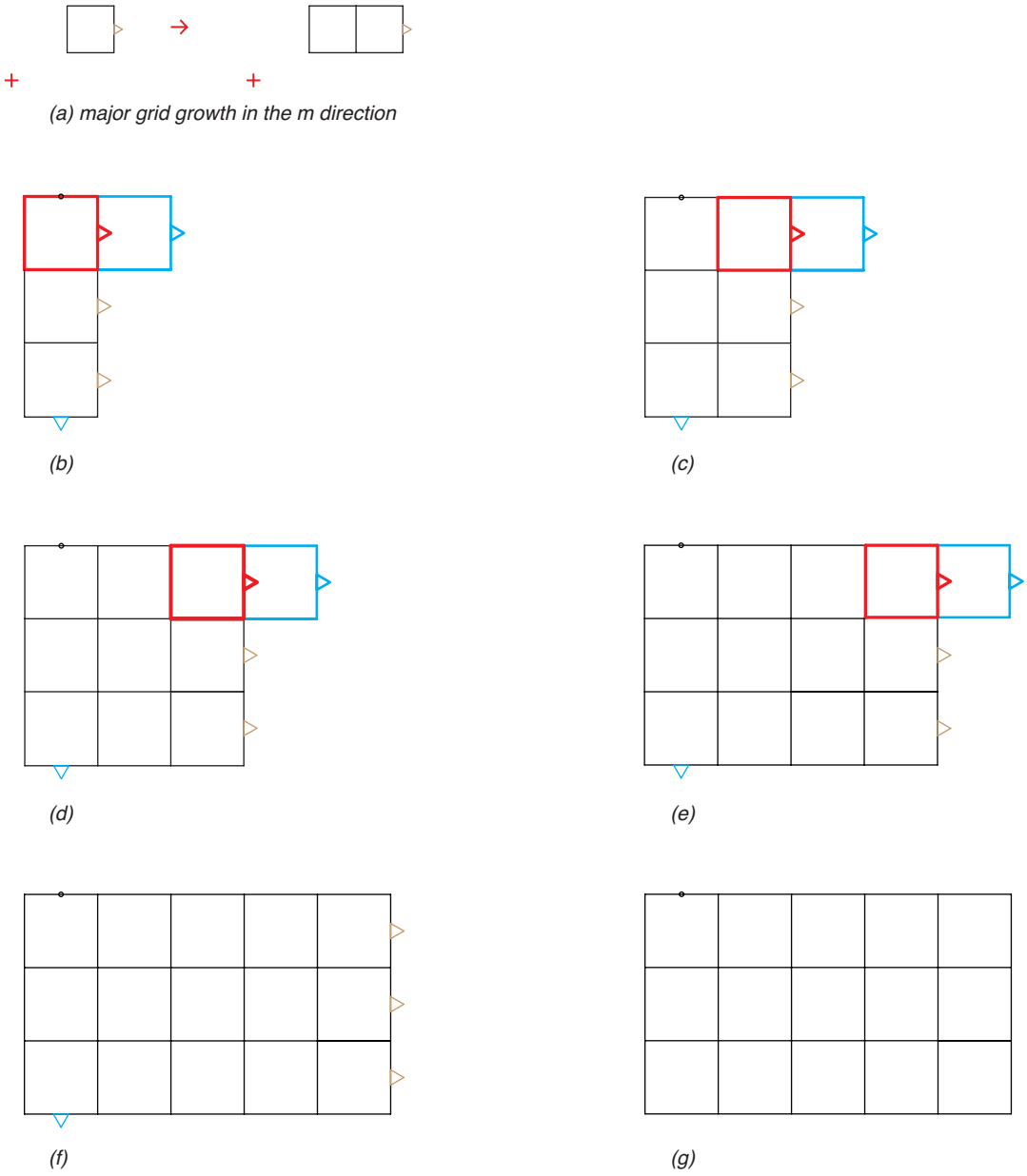


Figure 4.3 Entelechy grammar - Rule 2 to define major modules in the *m* direction: (a) rule; (b) rule application 01; (c) rule application 02; (d) rule application of 3; (e) rule application 04; (f) 3 x 5 major grid design; and (g) 3 x 5 major grid design after labels are removed.

moves the triangular label to allow for recursive growth as prescribed to generate a specific grid. When this rule is applied starting with the design of Figure 4.2(e), three matches are found, one of which is shown in Figure 4.3(b). The rules are designed for rectilinear grids,

so this particular rule should be applied for all conditions found in the design to avoid irregular boundaries. This rule is implemented once under these conditions to generate a complete 3 x 2 grid. The 3 x 2 grid shape is the new starting point for a second application of the rule that also yields three matches, one of which is shown as a sample in Figure 4.3(c). The complete application of these findings generates a 3 x 3 major grid design. The rule is applied a third time to this shape, as shown in Figure 4.3(d), to generate a 3 x 4 major grid. The fourth and final application of the rule is shown in Figure 4.3(e) and follows the same process as in the previous applications of rule 2 to produce the final 3 x 5 major grid illustrated in Figure 4.3(f).[87] Once the major modules are defined, two subsequent utility rules (rules 3 and 4, see Figure 4.5) are applied to remove the two triangular labels and complete the major grid generation process, resulting in the clean 3 x 5 grid of fifteen major modules, shown in Figure 4.3(g).

With the major grid in place, the final rule of this stage develops the minor grid layer to conclude the definition of the modular framework of Entelechy I. The minor grid is characterized by the definition of a secondary dimension of space centered at the corner intersections of the major grid as specified in rule 5, shown in Figure 4.4(a). The *LHS* of this rule includes a single major module of the grid. When this condition is found, the *RHS* implements a minor grid on a separate layer to disambiguate the dual conditions of the modular framework. When rule 5 is applied to the 3 x 5 major grid of Figure 4.3(g), fifteen matches are found. A single match is shown in Figure 4.4(b). Due to the role of this rule in generating the entire minor grid, rule 5 is applied for all matches so that a design is

[87] As with the previous rule for the growth of the major grid in the *n* direction, rule 2 is also limited in the number of applications permitted in a production because the shape rules are tailored for a specific range of major grids – from the 2 x 2 to the 4 x 6 to characterize a variety of single-family residential designs. Therefore, the rule may be applied up to a maximum of 5 times to allow for an *m* of up to 6.

achieved with the complete modular framework as shown in Figure 4.4(c).

In summary, all five rules of stage 1 (Figure 4.5) are used to produce a modular framework for any design generated with the shape rules of the Entelechy grammar. Rules 1 and 2 generate the major modules in the *n* and *m* dimensions, respectively, to achieve a rectilinear *n* x *m* grid composed of square modules. Rules 3 and 4 are utility rules to remove the triangular labels that guided major module growth in rules 1 and 2. Rule 5 terminates this stage by adding a minor grating that characterizes the major-minor tartan grid and completes the stage 1 production of a design. The resulting modular framework provides a woven canvas for further development in stage 2 to define the configuration of Entelechy I.

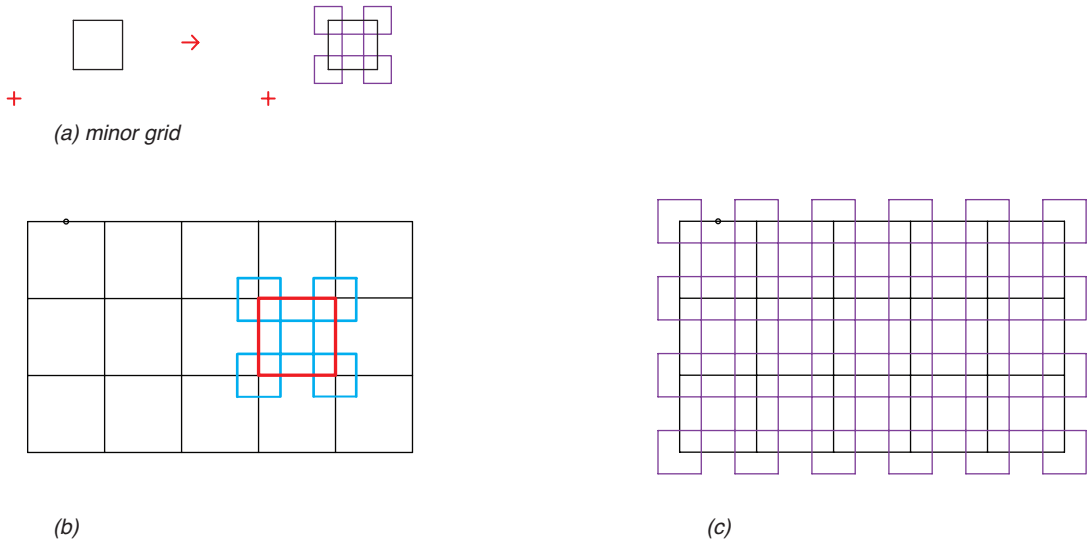


Figure 4.4 Entelechy grammar Rule 5 - to define the parameters of the minor grid: (a) rule; (b) rule application 01; and (c) 3 x 5 framework.

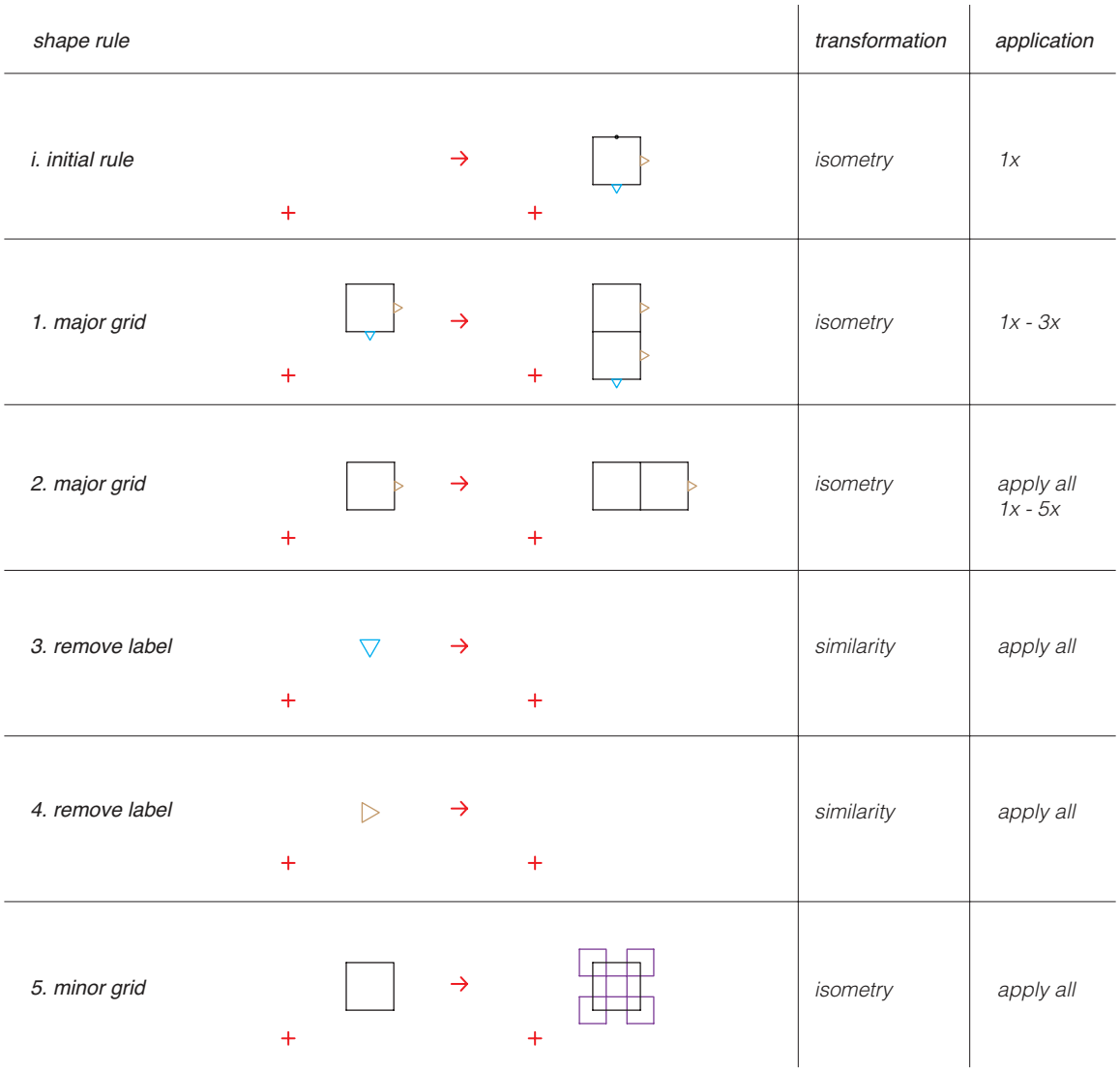


Figure 4.5 Entelechy grammar: initial rule and Stage 1 rules.

4.3 Stage 2: Configuration

The second stage of the production process focuses on developing the modular framework into a configuration reflecting the conceptual organization of spaces in Entelechy I. This stage transforms the dual modularity of the tartan grid into a configuration characterized by: a) the organization of figures; b) their orientation to articulate specific intersections; c) an entry sequence that defines circulation halls extending connection in

Entelechy I; and d) the distribution of double and single-height volumes that simultaneously reinforce thresholds and permit spatial connections. The configuration stage is the heart of a production in how it resolves the spatial organization of Entelechy I within the specificity of the underlying framework.

The process to define a configuration starts with the replacement of the minor grid with a figure that articulates the same dimensions in another form. Rule 6, illustrated in Figure 4.6(a), specifies a *LHS* that matches a part of the minor grid, the square corner definition and its linear extensions, and replaces it on the *RHS* with a circular figure of the same diameter. Figure 4.6(b) shows one match of the twenty-four non-equivalent matches found when this rule is applied to the modular framework developed in stage 1 (Figure 4.4(c)). The application of this rule for all twenty-four matches generates the design shown in Figure 4.6(c) – the characteristic underlying structure of Entelechy I, a 3 x 5 grid of fifteen square modules with twenty-four circular figures. Rule 6 essentially transforms the

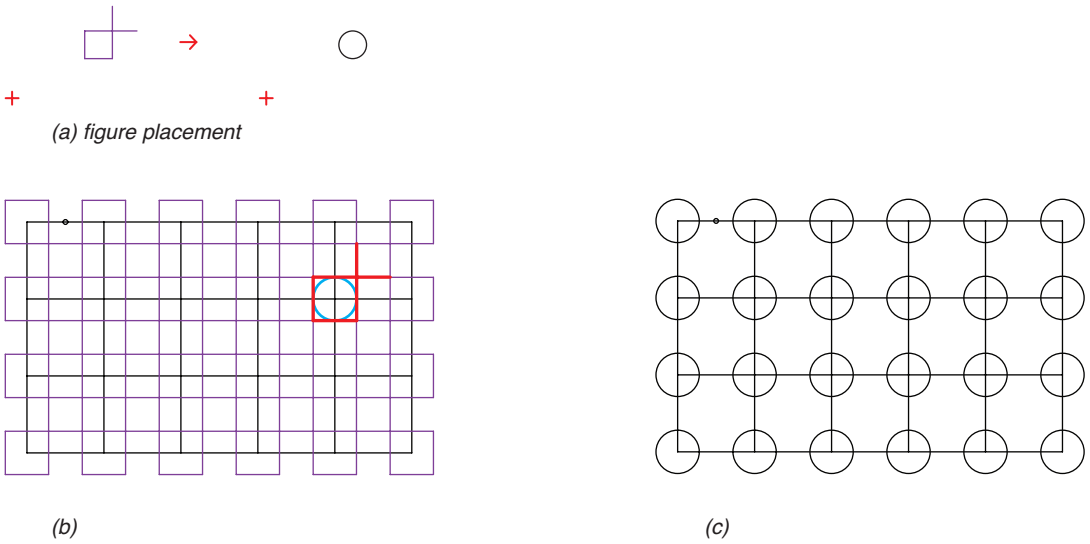


Figure 4.6 Entelechy grammar - Rule 6 for figure placement: (a) rule; (b) rule application 01; and (d) design produced after application of rule.

tartan structure of the modular framework into a distinctive figure-field configuration, represented in the contrasting spatial relationships between the curvilinear figures and the rectilinear field. In this move, the emergent major space becomes visible with its eight-sided shape of alternating linear and curvilinear segments defined by the figural minor spaces repeated at its corners.

Following the definition of figures, a series of rules specifying their relationships to particular intersections are given in Figure 4.7. These rules are indispensable in how they disambiguate the spatial relationships between figures and unique intersections at four conditions in Entelechy I. Specifically, rules 7 (Figure 4.7(a)), 8 (Figure 4.7(b)), and 9 (Figure 4.7(c)) specify rules for three conditions - interior, perimeter exterior/interior, and exterior corner figures, respectively. These rules are similar in the sense that each is composed of a *LHS* that defines a figural intersection in the grid and a *RHS* that trims the *LHS* shape to effectively label this condition visually. More precisely, the application of rule 7 defines the interior figures and results in eight matches in Entelechy I, one of which shown as a sample in Figure 4.7(f); the application of rule 8 defines the perimeter exterior/interior figures and results in twelve matches in Entelechy I, one of which shown as a sample in Figure 4.7(g); and the application of rule 9 defines the exterior corner figures and results in four matches in Entelechy I, one of which shown as a sample in Figure 4.7(h).

To complete the definition of figural intersections, two additional rules are used to specify exterior figures on the front entry-side of a configuration. Rule 10 (Figure 4.7(d)) initiates the definition of the entry side by describing a *LHS* consisting of a spatial relationship between an exterior corner figure and a perimeter exterior/interior figure spaced one major module apart on the front-side as denoted by the small circular label

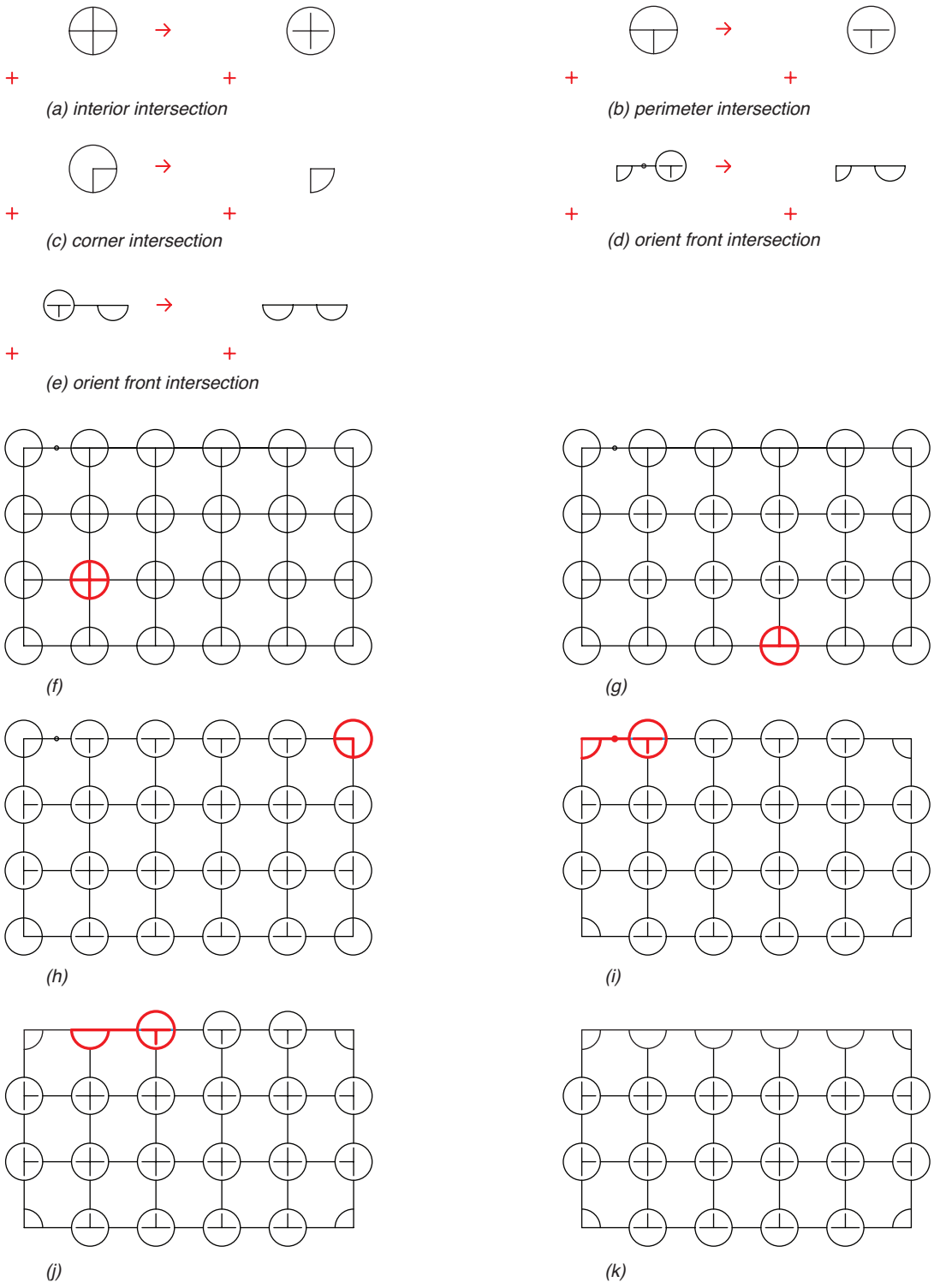


Figure 4.7 Entelechy grammar - Rules 7-11 to characterize figural intersections: (a) rule 7; (b) rule 8; (c) rule 9; (d) rule 10; (e) rule 11; (f) rule 7 application 01; (g) rule 8 application 01; (h) rule 9 application 01; (i) rule 10 application 01; (j) rule 11 application 01; and (k) design produced after application of rules 7-11.

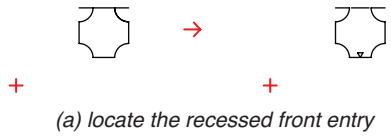
marking this corner in a design. On the *RHS,* this front label is removed, and the perimeter exterior/interior figure is relabeled with a half-circle shape to demarcate the front orientation of the design. When this rule is applied to the design of Figure 4.7(h), one match is found as shown in Figure 4.7(i). After this is implemented, rule 11 (Figure 4.7(e)) should be applied to continue the definition of the front side incrementally across a configuration. Rule 11 achieves this with a *LHS* that finds the spatial relationship between the new half-circle shape and an adjacent exterior/interior figure with a t-shape inscribed inside spaced one major module apart and a *RHS* where the exterior/interior figure is relabeled with a half-circle to extend the definition of front-facing figural intersections. For Entelechy I, a sample match of rule 11 is shown in Figure 4.7(j). Three sequential applications of rule 11 complete the front orientation to produce the design of Figure 4.7(k).[88]

The next series of rules in the configuration stage focus on the entry sequence and circulation halls that direct connection within Entelechy I. Rule 12 (Figure 4.8(a)) begins this definition by locating the recessed front entry. This rule consists of a *LHS* that locates a single eight-sided major space on the front orientation side of a design and a *RHS* where the outline of the major space is trimmed and a triangular label is added towards the interior to mark the recessed entry. When this rule is applied to the Entelechy I design in

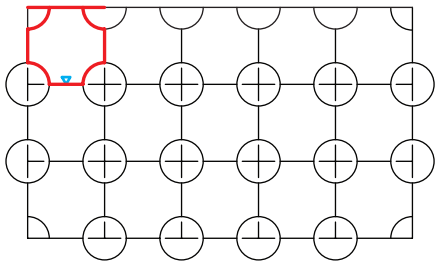
---

[88] This set of five rules are deliberately designed to only utilize a single layer in their specification and execution. They could easily be drafted in another way to more blatantly (and perhaps efficiently) highlight the various orientations and information they represent in defining the four figural intersections. However, this was avoided to demonstrate how spatial relationships can represent this knowledge directly in geometry to mirror how a designer might read a configuration scheme in a hand-drawn drawing. For example, a designer might know that the orientation of the drawing is precisely related to an entry side that is analogous to the top of a sheet of paper or related by the use of a drafting convention like a north arrow, etc. While this is fairly straightforward to a human designer, this is the kind of intuitive encoding that needs to be formalized in a series of shape rules to bring the machine up to speed.

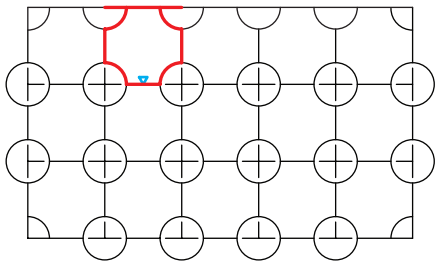
progress, five matches are found as shown in Figure 4.8(b), (c), (d), (e), and (f). Any of these locations are possible entries for a design, but this rule should only be applied once



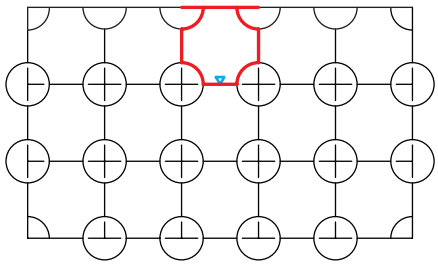
(a) locate the recessed front entry



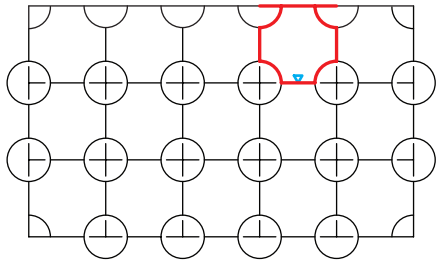
(b)



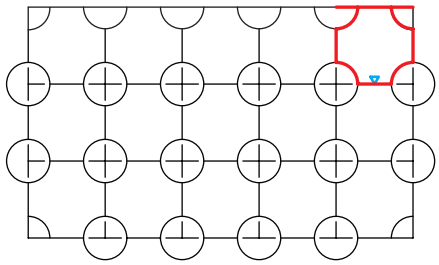
(c)



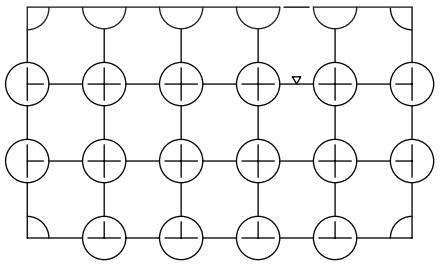
(d)



(e)



(f)



(g)

Figure 4.8 Entelechy grammar - Rule 12 to specify the recessed front entry: (a) rule; (b) rule match 01 of 05; (c) rule match 02 of 05; (d) rule match 03 of 05; (e) rule match 04 of 05; (f) rule match 05 of 05; and (g) design produced after application of rule.

so that a single entry is provided. To follow the development of the design for Entelechy I, the match shown in Figure 4.8(e) is selected to produce the design of Figure 4.8(g).

From the recessed entry, the entry axis is extended to define the connection sequence for circulation in the *m* direction. This extension is achieved with two additional parts of the entry axis consisting of: a) an interior foyer that meets the entry; and b) a view that follows the entry axis out to the surrounding exterior site. Two rules are used to achieve these spatial relationships in Entelechy I. Rule 13, shown in Figure 4.9(a), specifies the entry foyer with a *LHS* that finds a major space opposite the recessed entry and a *RHS* that labels it as the interior foyer. The application of this rule is previewed in Figure 4.9(c). Following the application of rule 13, rule 15 is applied to produce the view from the entry axis for designs with an *m* greater than 2 (Figure 4.9(b)).[89] This rule is composed of a *LHS* that locates a spatial relationship between the two smaller circular labels marking the edges of the foyer and lines outlining an adjacent major module on axis with the entry. Then, the *RHS* of the rule produces a view out from the foyer via a double-height volume denoted by the X-shape created in the rule within the additional major module. The application of this rule yields one result as previewed in Figure 4.9(d). When rules 13 and 15 are applied, the design of Figure 4.9(e) is generated with the entry axis resolved to consist of an interior foyer and a double-height volume that creates a view out to the backyard (which in Entelechy I provides a skyline view to downtown Atlanta) as well as down to the interior below.

The expansion of a secondary path of connection is achieved in the next rule that

[89] Rule 14 is skipped here because it reflects an additional shape rule that extends a double foyer for designs larger than Entelechy I, specifically those with an *m* of 4 (see Figure 4.14).

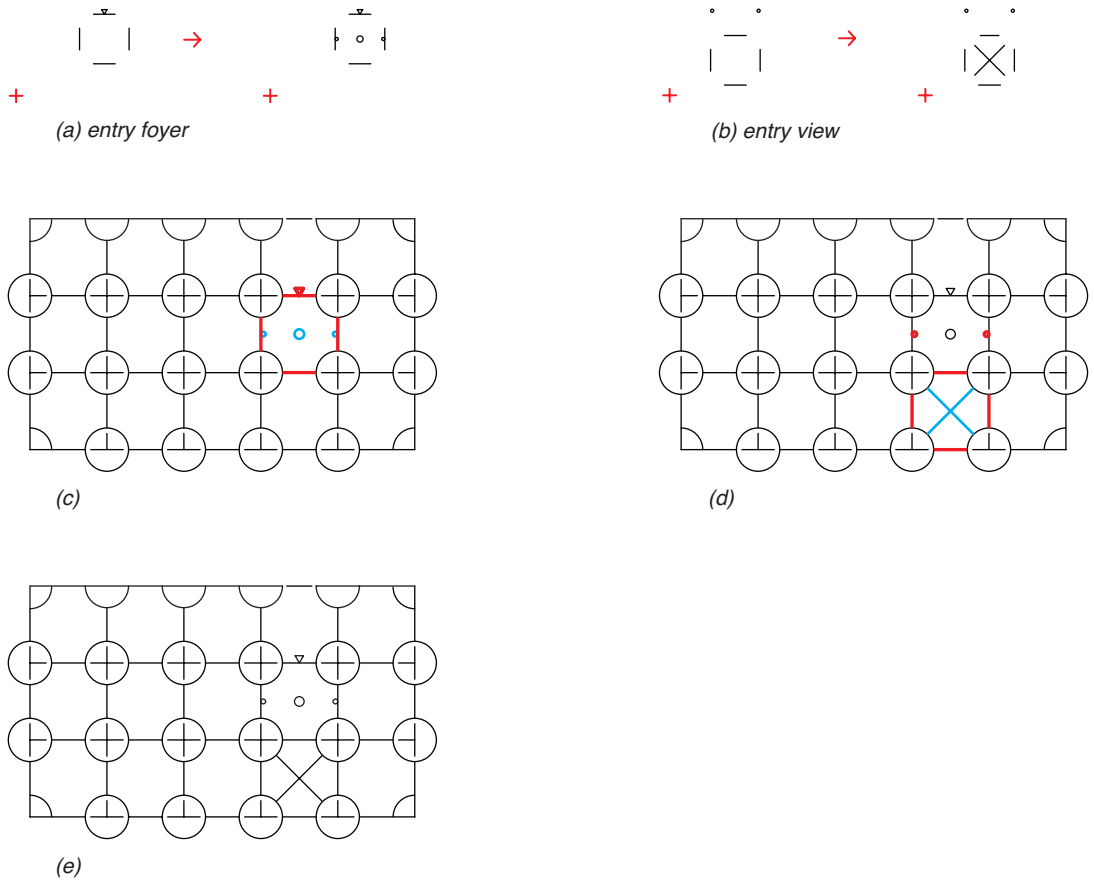


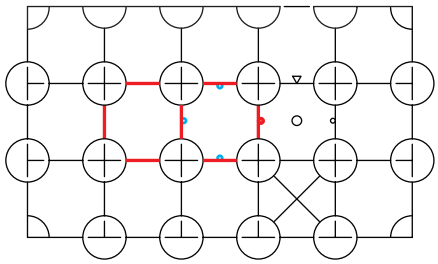
Figure 4.9 Entelechy grammar - Rules 13 and 15 to define the entry axis: (a) rule 13; (b) rule 15; (c) rule 13 application 01; (d) rule 15 application 01; and (e) design produced after application of rules.

opens the interior circulation hall. Shown in Figure 4.10(a), Rule 16 is activated by one of the small circular labels at the entry foyer and its relationship to two additional major modules in the *n* direction as defined by the *LHS* of the rule. When this condition is met, the *RHS* of the rule translates the circular label and adds two additional labels to extend a central circulation hall. To generate the connections of the circulation hall in Entelechy I, two applications of this rule are needed so that none of the perimeter spaces are inaccessible. The first application is previewed in Figure 4.10(b). Once this is applied, a

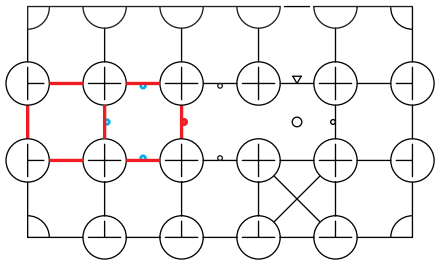
second application is possible, as previewed in Figure 4.10(c) and implemented in Figure 4.10(d) to open the central circulation hall of Entelechy I.[90]

After circulation halls are defined, a series of rules to organize the major volumes Entelechy I are applied. The distribution of these double-height volumes can happen

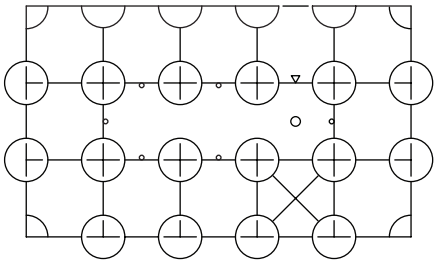
(a) to open the circulation hall



(b)



(c)



(d)

Figure 4.10 Entelechy grammar - Rule 16 to open the circulation hall: (a) rule; (b) rule application 01; (c) rule application 02; and (d) design produced after application of rule.

[90] Rules 17, 18, and 19 are additional shape rules to define possible circulation halls that interpret possibilities not considered in Entelechy I, but proposed here to represent an expanded domestic system. Specifically, rule 17 is an additional shape rule to specify a circulation hall with a doubled depth of two major modules for designs with an *m* of 4. Rules 18 and 19 allow for the circulation hall to extend to the exterior perimeter of a configuration to allow for views out from the interior along the secondary axis for designs with an *m* of 3 or less and designs with an *m* of 4, respectively (see Figure 4.15).

anywhere along the central circulation hall as indicated by the smaller circular labels. Rule 20, shown in Figure 4.11(a), puts this into practice with a *LHS* that finds an exterior major module at the perimeter connected directly to the central hall as denoted by the circular label and a *RHS* that removes the circular label and adds an X-shape to represent the production of a major double-height volume when the rule is applied. The central hall configuration of Entelechy I allows for six possible applications of this rule and these options are simulated in Figure 4.11(b), (c), (d), (e), (f), and (g). The rule is applied for one match at a time and can be used as desired to define open volumes along the central hall that offer views out to the surrounding site and down across the double-height spaces that connect to the interior below.

Nonetheless, the rule should be applied considering the fact that every open volume is a perimeter space that cannot be developed as a single-height room on either the upper or lower level of a design. While it is possible to apply this rule for all conditions, the result will produce an open loft-like design with no enclosed or semi-enclosed rooms at the major scale. A more efficient program, like the design of Entelechy I, only applies this rule once to match the condition of Figure 4.11(g). This particular choice produces the design of Figure 4.11(h) and initiates a division where the double-height volume is only on one side of the main entry axis while the other side is left for development as rooms, creating a social boundary between shared public volume and single-height private or semi-private spaces in the design of Entelechy I.

Once the major double-height volumes along the central hall are coordinated, a series of shape rules for connecting larger continuous volumes are provided. These rules are used to craft the form of the double-height space and even more to solve functional issues at corner conditions, where spaces can easily become inaccessible due to the fact

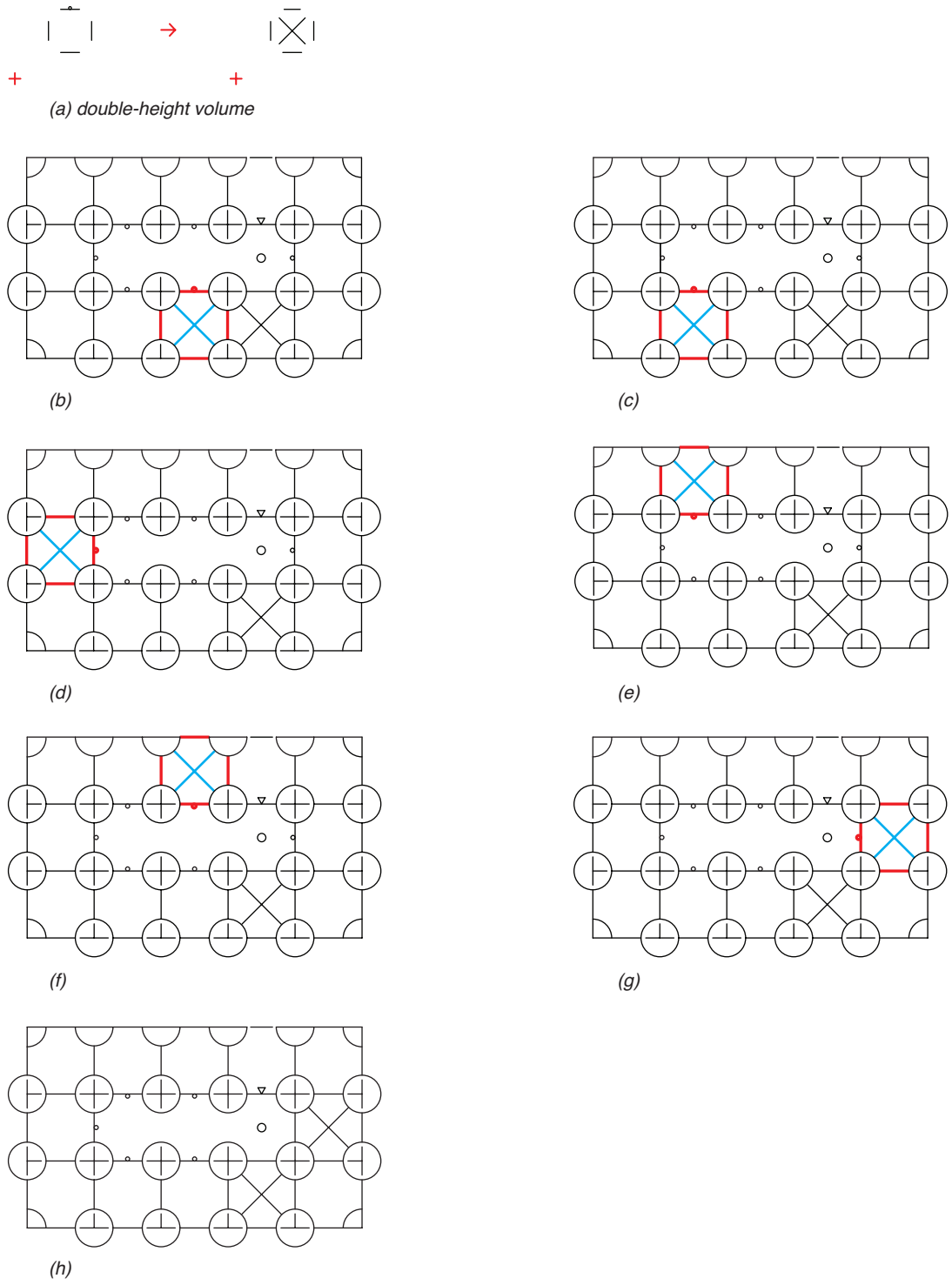


Figure 4.11 Entelechy grammar - Rule 20 to define major double-height volumes: (a) rule; (b) rule match 01 of 06; (c) rule match 02 of 06; (d) rule match 03 of 06; (e) rule match 04 of 06; (f) rule match 05 of 06; (g) rule match 06 of 06; and (h) design produced after application of rule.

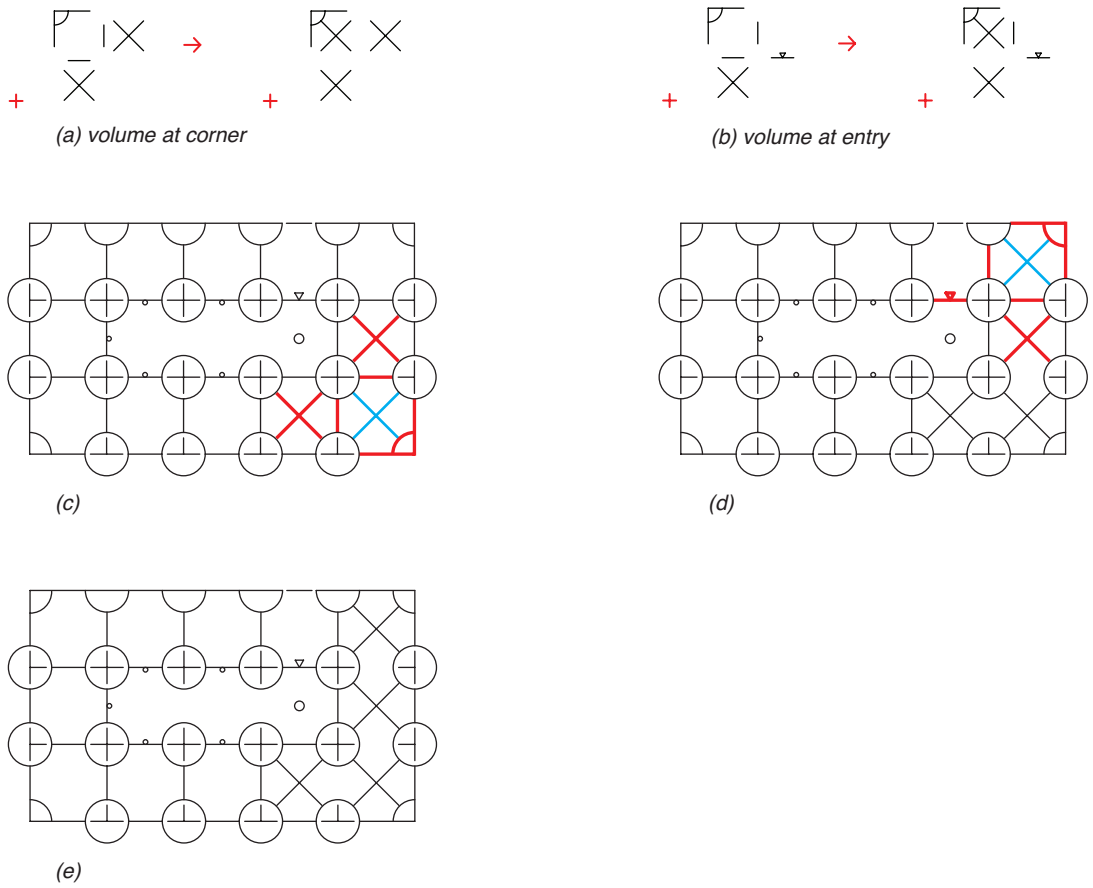


Figure 4.12 Entelechy grammar - Rules 21 and 22 to define double-height volumes at corner conditions: (a) rule 21; (b) rule 22; (c) rule 21 application 01; (d) rule 22 application 01; and (e) design produced after application of rules.

that lateral circulation in Entelechy I is handled primarily by the central hall. For this reason, these rules must be applied for all conditions where a match is found. Rule 21 concatenates a corner double-height volume across three major modules as shown in Figure 4.12(a). The rule includes a *LHS* that looks for a corner major module adjacent to major double-height volumes on two sides as denoted by the X-shapes and a *RHS* that removes the linear divisions of the major grid between these spaces and adds a third double-height volume to effectively create a continuous open L-shape in the design as illustrated in Figure 4.12(c). Next, rule 22 (Figure 4.12(b)) is applied to address a similar condition adjacent to the recessed entry as described by the *LHS* of the rule. Here, the

RHS removes the linear division adjacent to the existing double-height volume and adds a second double-height volume at the corner. In addition, the linear division of the major grid between the new volume and the recessed entry is maintained to ensure the integrity of the enclosing boundary at the recessed entry. A single match for this rule is found in Figure 4.12(d) and produces the design in Figure 4.12(e).[91]

The final shape rules of stage 2 address single-height volumes that extend the central circulation hall. These extensions serve dual purposes. First, on the interior they create semi-private vestibules off of the main hall that can provide access to adjacent spaces. This is necessary for any corner room, which is otherwise blocked from direct access to the circulation hall. Second, on the exterior they provide a half-module at the major scale that defines a service zone in Entelechy I for allocating plumbing vertically throughout a design. Rule 25 (Figure 4.13(a)) develops these hall extensions/half-modules adjacent to corner spaces as depicted in the *LHS*, which locates the spatial relationship between a quarter-circle shape of the corner figure and an adjacent major space connected to the circulation hall with a circular label. When this condition is satisfied, the *RHS* translates the labeled line toward the exterior, extends it to create perpendicular sides, and reflects the circular label so that it is within the new half-module. When this rule is applied to the design of Figure 4.12(e), three non-equivalent matches are found as illustrated in Figure 4.13(b), (c), and (d). This rule should be applied one match and a time recursively until no matches are found to ensure that all corner rooms are accessible. To complete the production of Entelechy I in this stage of the grammar, this rule is applied

[91] Rules 23 and 24 are not used in the production of Entelechy I but each address the further articulation of major volumes. Rule 23 allows for any corner extension to connect double-height spaces and rule 24 is a utility rule for removing the linear division between adjacent double-height spaces at the perimeter (see Figure 4.15 and Figure 4.16).

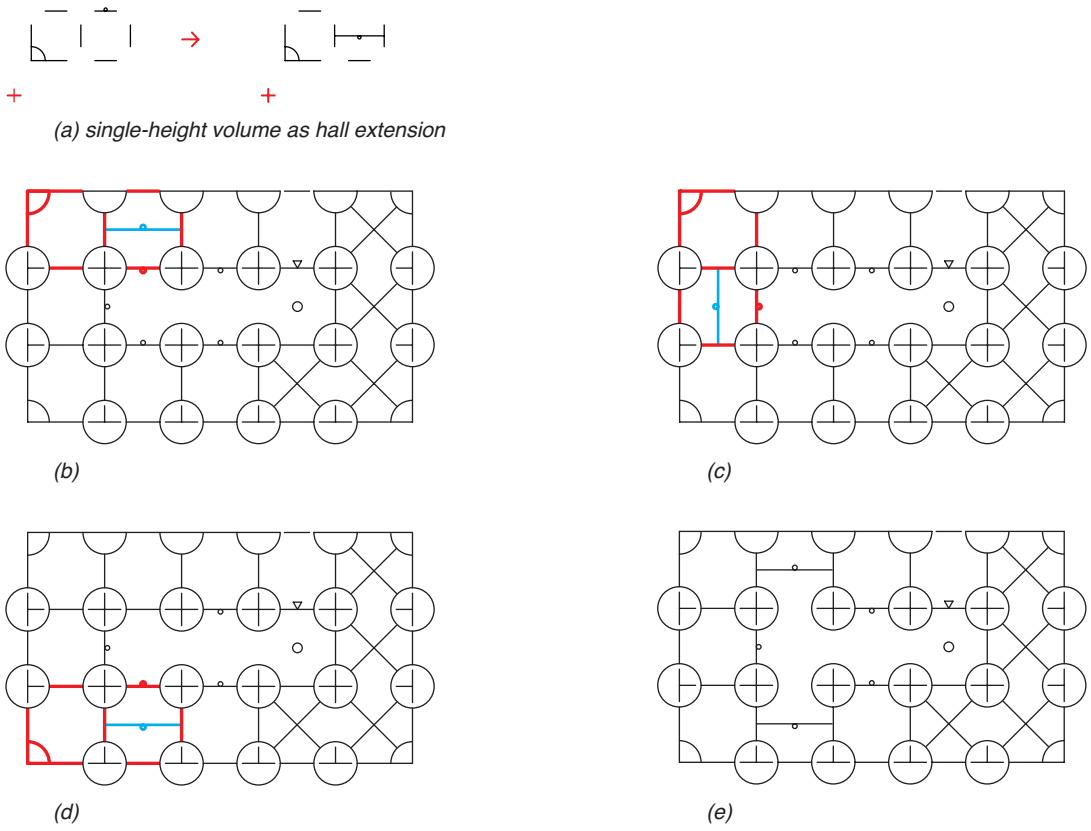


Figure 4.13 Entelechy grammar - Rule 25 to differentiate single-height volumes as hall extensions: (a) rule; (b) rule match 01 of 03; (c) rule match 02 of 03; (d) rule match 03 of 03; and (e) design produced after application of rule.

once for the match of Figure 4.13(b) and a second time for the match of Figure 4.13(d) to produce the design of Figure 4.13(e).[92]

In summary, the shape rules of stage 2 are used to transform a framework into a configuration of Entelechy I. A configuration is characterized by the integration of module, figure, intersection, connection, and volume to compose an intricate structure of key spatial relations in a design. Rule 6 replaces the rectilinear minor grid lines with circular figures that concisely and directly articulate the same module. Rules 7-11 are orientation

[92] The last rule of stage 2, rule 26, is a variation of rule 25 that creates hall extensions/half-modules anywhere along the interior (see Figure 4.16).

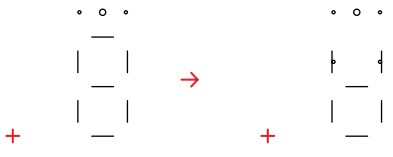
shape rule	*transformation*	*application*
6. figure 	*isometry*	*apply all*
7. figure_interior 	*similarity*	*apply all*
8. figure_perimeter 	*similarity*	*apply all*
9. figure_corner 	*similarity*	*apply all*
10. orient front 	*similarity*	*1x*
11. orient front 	*similarity*	*1x loop all*
12. front entry 	*similarity*	*1x*
13. entry foyer 	*similarity*	*1x*
14. extend foyer 	*similarity*	*1x*

Figure 4.14 Entelechy grammar: Stage 2 rules 6-14.

shape rule	*transformation*	*application*
15. entry view	*similarity*	*1x*
16. open hall	*similarity*	*1x loop all*
17. open hall x2	*similarity*	*1x loop all*
18. hall extension	*similarity*	*free*
19. hall extension x2	*similarity*	*free*
20. double-height (dh)	*similarity*	*free*
21. dh at corner x2	*similarity*	*apply all*
22. dh at entry	*similarity*	*apply all*
23. dh at corner	*similarity*	*free*

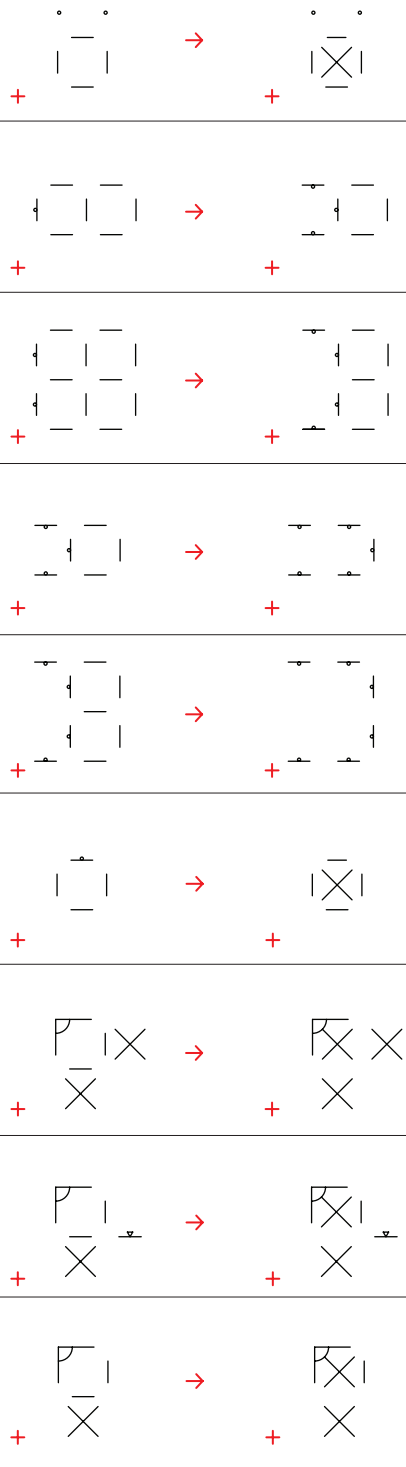


Figure 4.15 Entelechy grammar: Stage 2 rules 15-23.

shape rule	transformation	application
24. open adjacent dh 	similarity	apply all
25. half module 	similarity	1x loop all
26. half module 	similarity	free

Figure 4.16 Entelechy grammar: Stage 2 rules 24-26.

rules for the figures to define particular intersections within a configuration. Rule 12 begins the development of circulation by specifying the recessed front entry as an initial threshold of connection. Rules 13, 14*, and 15 extend the connection path along the main entry axis. Rules 16, 17*, 18*, and 19* open circulation halls in the other direction, providing connection perpendicular to the main entry axis. Rule 20 defines major double-height volumes along the central circulation hall. Rules 21, 22, 23*, and 24* concatenate major double-height volumes to define L-shapes at corners as well as additional extensions adjacent to the entry, corners, or other double-height volumes. Lastly, rules 25 and 26* specify single-height volumes as hall extensions that create vestibules for access to adjacent spaces as well as half-module spaces to distribute plumbing services.

Of the twenty-one rules in this stage, fourteen are implemented in the automation of the original design for Entelechy I and have been discussed in detail here to illustrate their intent and expressiveness. For purposes of brevity and clarity, the additional seven

rules developed to interpret other possibilities for the house language were only briefly introduced (each of these shape rules is denoted by an asterisk * in the summary above). Their effects will be seen in the set of designs produced from the software and in addition, they are each illustrated in the complete ruleset shown in Figure 4.14, Figure 4.15, and Figure 4.16). In all, the resulting configuration of Entelechy I articulates the core spatial organization of the house in preparation for further development in stage 3.

4.4 Stage 3: Architectonics

The third and final stage of the Entelechy grammar elaborates a design from a conceptual sketch to an architectonic representation in plan. The architectonics of each design specified with the Entelechy grammar are generated by articulating: a) linear walls; b) curvilinear walls and structure; c) stairs; d) interior details; and e) interior/exterior details. These parts are typical elements of buildings, but each is deployed in a precise way here to conform to the formal system of the house. The architectonic stage is the most involved, consisting of forty rules that develop a design to the level of detail expected of an architectural floor plan that conceptually describes spaces, structure, circulation, and materials.[93]

[93] Of this ruleset, twenty-seven shape rules are applied in the architectonic production of Entelechy I. Still, this subset includes seven utilitarian rules for clarifying labels and details of architectural representation that are important to the generation process, but not as crucial in understanding the fundamentals of the language in terms of spatial relationships and design principles. For this reason, the main twenty rules will be the primary focus of the description here, with brief explanations on the secondary set of seven rules. As before in previous stages, the thirteen rules not used in the production of Entelechy I are interpretive and/or utility shape rules that will be conceptually covered here to understand how they fit into the overall structure of the implementation. All rules are included at the end of this section for reference.

Clarifying the architectonic detail of a configuration towards a working plan begins with a thickening process to go from a single-line organization to a double-line representation conveying volumetric elements. The articulation of walls starts the process, which is accomplished with a series of four shape rules. These rules are used to define three wall-types: a) shorter straight walls that partition major spaces between figural minor spaces; b) longer straight walls that partition half-modules; and c) exterior glass partition walls. Rule 27, as shown in Figure 4.17(a), is first applied to find the shorter line segments between figural minor spaces as depicted on the *LHS* of the rule and then to replace them as thickened walls on the *RHS*. A sample match of this rule applied to the design of Entelechy I is given in Figure 4.17(e). Once the shorter walls are thickened, rule 28 (Figure 4.17(b)) addresses the longer line segments that span the full width of a major space at half-modules as shown in the *LHS* of the rule and matched for one condition in Figure 4.17(f). When rules 27 and 28 are applied for all matches, each straight wall of a design will be thickened.

Two subsequent rules, 29 and 30, are then used to articulate transparent exterior walls that contrast the otherwise solid interior partitions. Rule 29 (Figure 4.17(c)) initiates this definition starting from the exterior corners as specified in the *LHS* of the rule. When this condition is met, a third centerline will be added to the wall to represent transparent glazing as shown on the *RHS* of the rule. Figure 4.17(g) highlights a single match for this rule, which is one of four matches in the 3 x 5 design, each addressing a single corner. This rule should be applied for all conditions in parallel so that rule 30 can properly continue the definition of transparent exterior walls. Rule 30 (Figure 4.17(d)) picks up where rule 29 left off by describing a spatial relationship on the *LHS* that includes one of

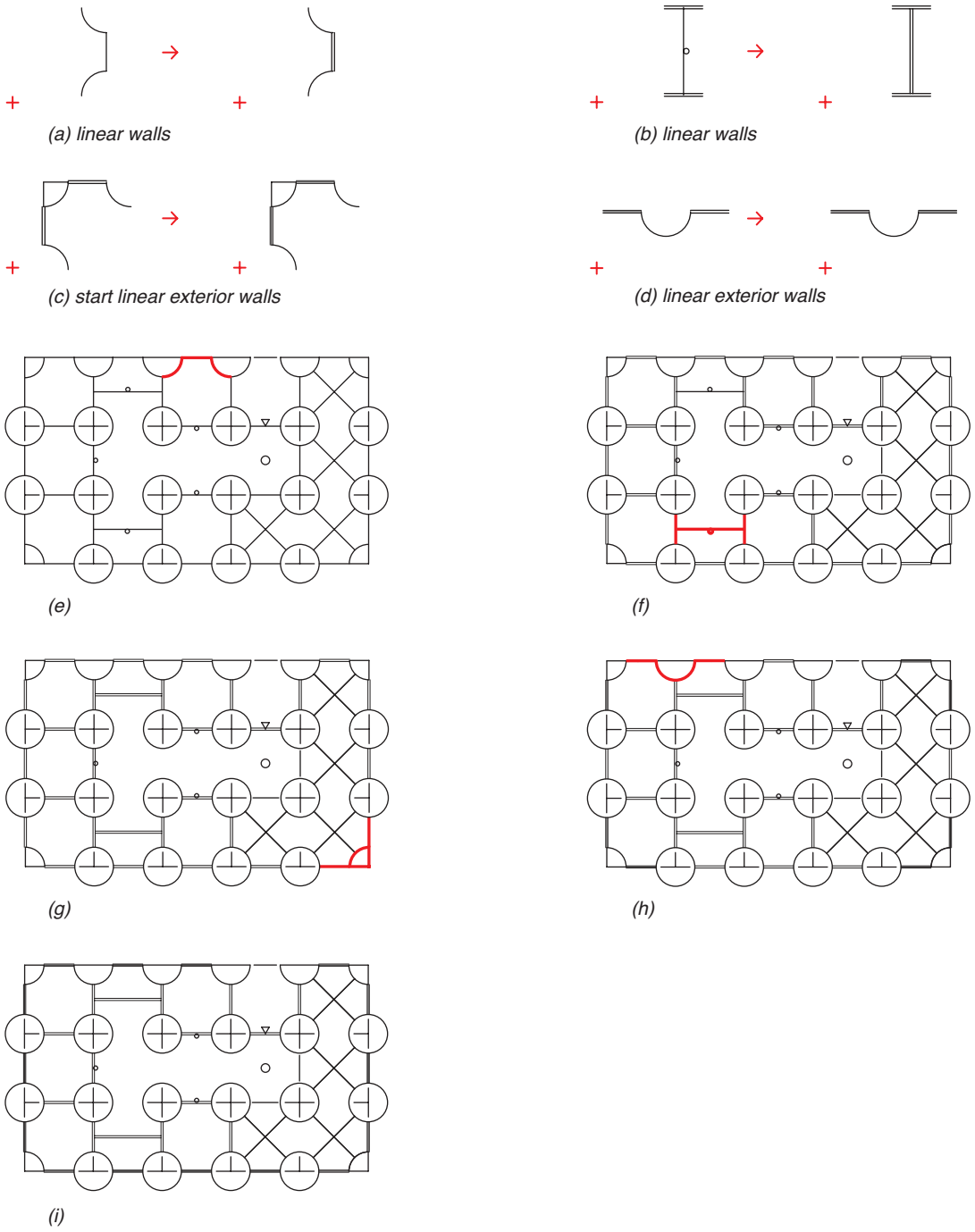


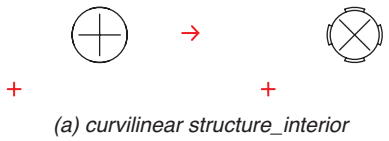
Figure 4.17 Entelechy grammar - Rules 27-30 to develop linear walls: (a) rule 27; (b) rule 28; (c) rule 29; (d) rule 30; (e) rule 27 application 01; (f) rule 28 application 01; (g) rule 29 application 01; (h) rule 30 application 01; and (i) design produced after application of rules.

the new three-lined partitions representing exterior glazing and an adjacent two-lined partition along the exterior boundary connected by the half-arc of a curvilinear figure in between them. Figure 4.17(h) illustrates a sample *LHS* match for this rule. When this relation is found, the *RHS* of the rule replaces the two-lined partition with a three-lined partition to continue the definition of exterior glazing. This rule should be applied for all conditions found recursively until the rule no longer applies. When these four rules are implemented, the details of linear walls will be complete throughout the interior and along the main body of the perimeter as depicted in Figure 4.17(i).[94] The unique detailing at the recessed entry, consisting of linear and curvilinear segments, is included in the next subset of rules.

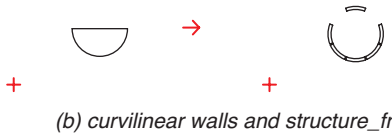
The thickening process continues with the definition of curvilinear walls and structure. Five rules are used to articulate these elements in Entelechy I. Rule 32 is applied first to define the four curvilinear structural wall segments of interior figures with a *LHS* that looks for single-line figures with cross-shapes centered on their interior as illustrated in Figure 4.18(a). When a match is found, like the example shown in Figure 4.18(f), the *RHS* of the rule replaces the outline of the figure with four curvilinear structural segments as well as a recomposed outline of the interior diameter with X-shaped linework inside to denote an open minor volume in plan.[95]

Moving to the exterior, rules 33 and 34 develop the curvilinear walls and structure along the perimeter. First, rule 33 (Figure 4.18(b)) defines the six curvilinear wall segments

[94] One additional rule, 31, removes a circular label when it meets an exterior partition (see Figure 4.23).
[95] This rule should be applied for all matches found in a design to generate the curvilinear structure that characterizes the interior hollow columns.



(a) curvilinear structure_interior

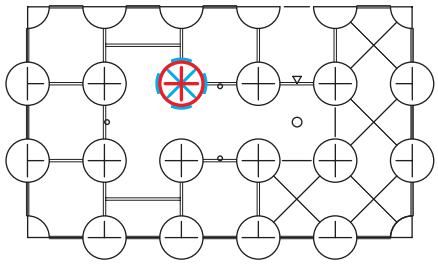


(b) curvilinear walls and structure_front

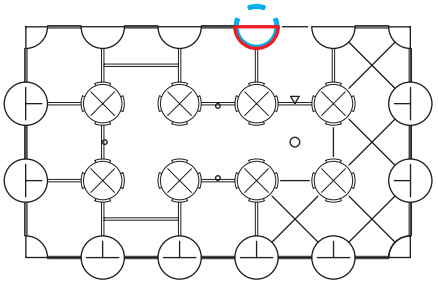
(c) curvilinear walls and structure_perimeter

(d) entry details

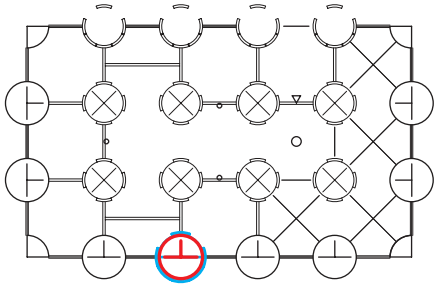
(e) curviliear walls and structure_corner



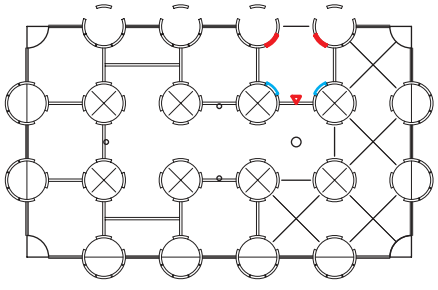
(f)



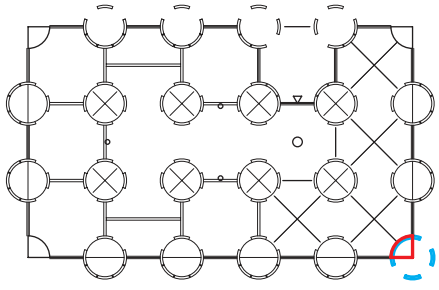
(g)



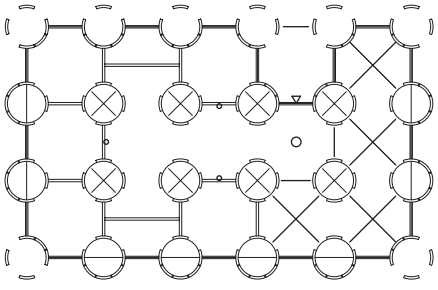
(h)



(i)



(j)



(k)

Figure 4.18 Entelechy grammar - Rules 32-34; 36-37 for curvilinear structure, walls: (a) rule 32; (b) rule 33; (c) rule 34; (d) rule 36; (e) rule 37; (f) rule 32 application 01; (g) rule 33 application 01; (h) rule 34 application 01; (i) rule 36 application 01; (j) rule 37 application 01; and (k) design produced after application of rules.

of exterior figures on the front-facing side of a design with a *LHS* that specifies their half-arc single-line figures and a *RHS* that replaces them with thickened segments including the four structural parts aligned to the cardinal axes and two additional curvilinear parts that complete the exterior enclosure. A sample match and preview application of this rule is illustrated in Figure 4.18(g). When rule 33 is applied for all matches found in a design, the open hollow columns across the front façade are complete. In the opposite fashion, the exterior figures on the three other faces of a design are closed to the exterior as described by rule 34 (Figure 4.18(c)). This shape rule is composed of a *LHS* that looks for the single-lined perimeter figures with T-shapes on their interior. When a match is found, like the example in Figure 4.18(h), the *RHS* generates the same hollow column composed of six curvilinear segments that was created in the previous rule but flips the orientation so that the hollow columns effectively add space to the interior of a design.[96]

The final details of the exterior curvilinear walls and structure are achieved in rules 36-37, each defining a transition in the exterior enclosure. Specifically, rule 36 (Figure 4.18(d)) describes conventions for the recessed entries embedded within the front-façade to match the entry condition of Entelechy I.[97] The *LHS* of rule 36 describes the spatial relationship between the triangular label at the entry and two curvilinear segments at the front-facing hollow columns that precede the entry. The match for this is shown in Figure 4.18(i). When applied, the *RHS* adds the centerlines of the glass enclosure to the straight segments of the exterior walls lining the entrance, reflects the two curvilinear segments and translates them to seal the exterior corners at the recessed entry. The last rule for

[96] This rule should be applied for all conditions found in a design under the “apply all” mode in *Shape Machine*.

[97] Rule 35 depicts an alternate possibility to expand the housing system in Entelechy I. This additional rule, included in Figure 4.23, allows for entries to be specified at front-facing corners in a design.

curvilinear walls addresses the figures at exterior corners that terminate the edges of facades and negotiate transitions from one side to another. Rule 37 (Figure 4.18(e)) consists of a *LHS* that looks for these figures as marked by the closed quarter-arc shape and a *RHS* composed of five curvilinear segments that seals the exterior enclosure of a design. Figure 4.18(j) illustrates a match and preview for application at one corner of the design. When the rule is implemented for all matches, the design of Figure 4.18(k) is produced.

Once the linear and curvilinear enclosures are defined volumetrically and structurally, the architectonic development moves to fill the circular, hollow figures on the interior that now have articulated form. This process starts with the eight-foot diameter spiral staircases, the vertical circulation elements that the hollow columns (and minor module) are constrained precisely for. Rules 38, 40, and 43 relate to the three stairs in Entelechy I, which essentially provide public, semi-public, and semi-private vertical circulation in the original design.[98] Specifically, rule 38 initiates stair placement with a rule for the public stair at the entry foyer as shown in Figure 4.19(a) and previewed in Figure 4.19(d); rule 40 places a stair on the central hall as shown in Figure 4.19(b) and matched for one possible application in Figure 4.19(e); and rule 43 designates a stair for a loft study connected to a master suite on the lower level as shown in Figure 4.19(c) and located for

[98] Six shape rules, rules 38-43, describe the placement of stairs in the Entelechy grammar. All six rules are included in Figure 4.24. Each of these rules is similar in the sense that they all describe a *LHS* consisting of a spatial relationship between a circular open space of a hollow column (denoted by the X-shape or centerline inscribed in a circle) and adjacencies in the design that connect them to the entry foyer (rules 38-39), the circulation hall (rules 40-42), or a loft study (rule 43), if any. Additionally, their *RHS* replaces the open space with a spiral stair circumscribed by a broken circle to represent a spatial connection to access the stair. The three rules not used in the production of Entelechy I here (Rules 39, 31, and 42) are additional interpretations that expand possibilities for stair locations in the complete ruleset of the grammar.

the 3 x 5 design in Figure 4.19(f). The design in Figure 4.19(g) represents the singular application of all three rules to conclude stair placement in the production.

After vertical circulation is distributed in a design, additional interior details are taken on in two series: the first engages the form of the hollow column; and the second carries out a series of finer grain details in a design. Rules 44-49 focus on the first series to demonstrate the versatility of how the segmented curvilinear form is put to various uses

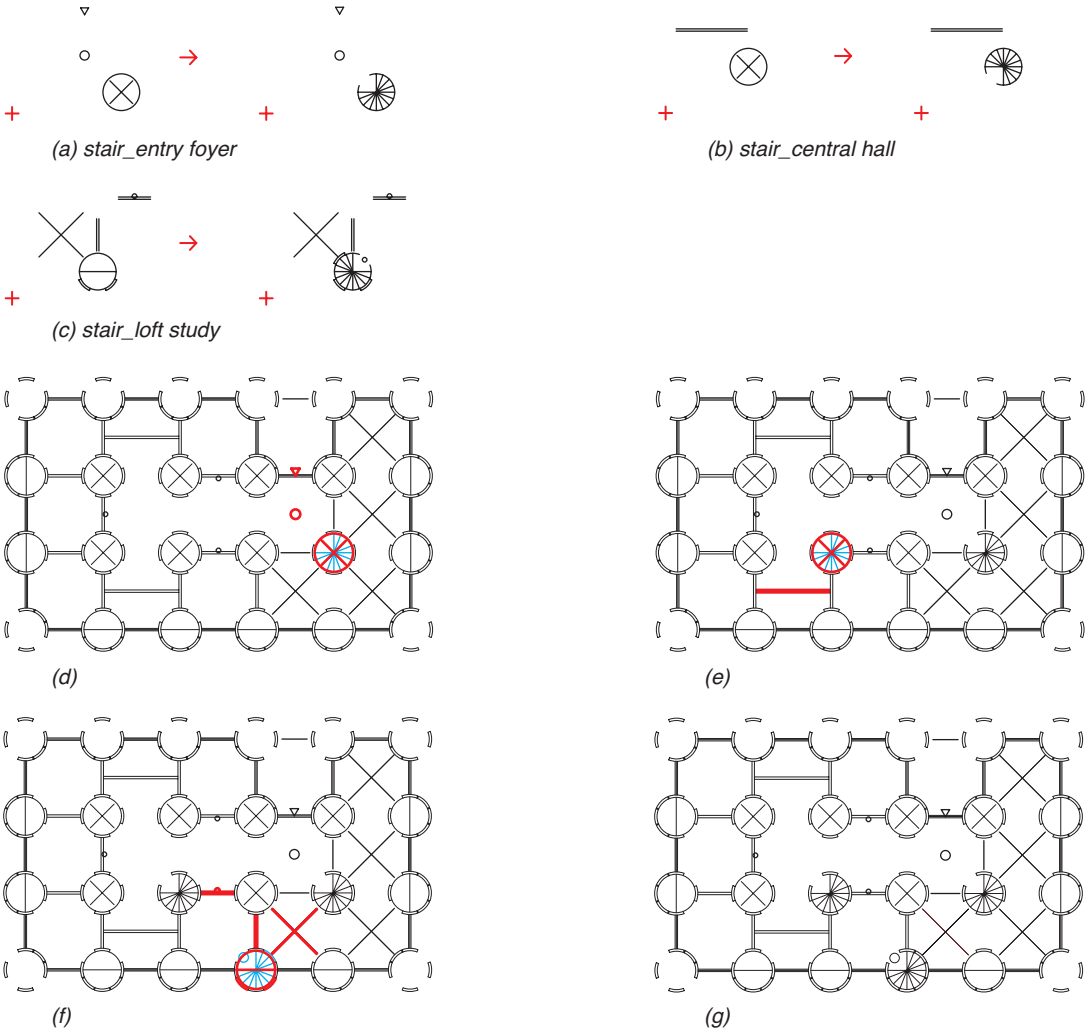
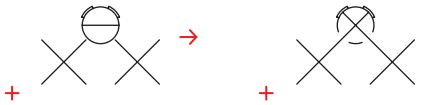


Figure 4.19 Entelechy grammar - Rules 38, 40, and 43 for locating stairs: (a) rule 38; (b) rule 40; (c) rule 43; (d) rule 38 application 01; (e) rule 40 application 01; (f) rule 43 application 01; and (g) design produced after application of rules.

in a design. Essentially, each of these shape rules describe a *LHS* consisting of a spatial relationship between a circular open space of a hollow column (denoted by the X-shape or centerline inscribed in a circle) and a specific context in the design. Then, when these conditions are met, the *RHS* replaces the interior of the hollow column with a representation of its assigned use. Five of these rules are illustrated in detail here (Rules 44, 46-49) to match conditions in Entelechy I. Specifically, rule 44 (Figure 4.20(a)) describes hollow columns that extend double-height volumes as previewed in Figure 4.20(e); rule 46 (Figure 4.20(b)) creates a half-bath and closet off of the entry foyer as previewed in Figure 4.20(f)[99]; rule 47 (Figure 4.20(c)) becomes a library for a loft study as previewed in Figure 4.20(g); and rule 48 (Figure 4.20(d)) closes a central double-height column for another use as previewed in Figure 4.20(h). When these four rules are applied to the design in progress, the result of Figure 4.20(i) is achieved.

The last shape rule of this first series of interior detailing rules, rule 49, is depicted in Figure 4.21(a) to describe a rule for locating bedrooms. More precisely, the *LHS* consists of a spatial relationship between a circular open space of a hollow column (denoted by the centerline inscribed in a circle) and a major space defined by thickened walls at its sides – at least one of which must be an exterior wall denoted by the triple-line representation of glazing. When these conditions are met as illustrated in the sample match of Figure 4.21(b), the *RHS* will develop the minor space inside the hollow column as a private study for an adjacent bedroom space, add three curvilinear segments to the major and minor space, respectively, to close them off at their corners, and provide a circular label in the center of the major space to denote a bedroom in subsequent rule

[99] Rule 45 is an alternative version of rule 46 that also allows for locating a half-bath and closet as depicted in the complete ruleset (see Figure 4.25).

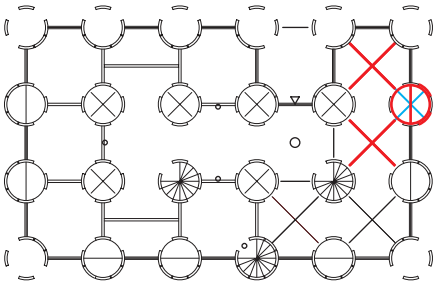


(a) minor details_extend volume

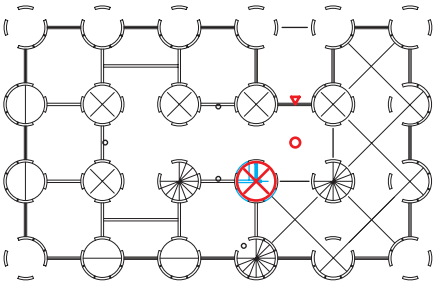
(b) minor details_half-bath/closet

(c) minor details_loft study library

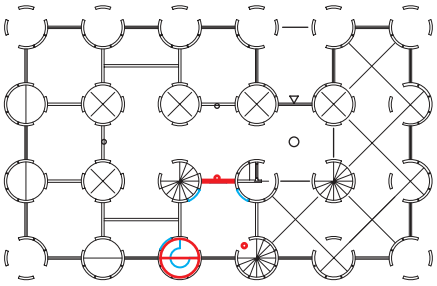
(d) minor details_front bedroom



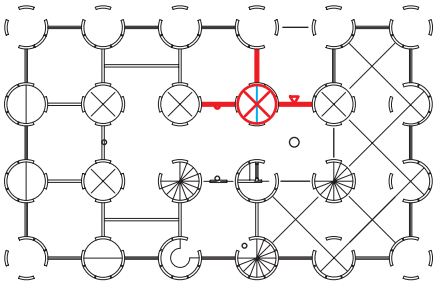
(e)



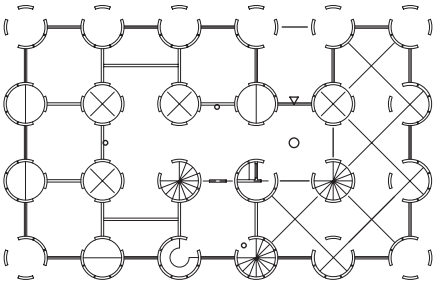
(f)



(g)



(h)



(i)

Figure 4.20 Entelechy grammar - Rules 44, 46-48 to specify interior details: (a) rule 44; (b) rule 46; (c) rule 47; (d) rule 48; (e) rule 44 application 01; (f) rule 46 application 01; (g) rule 47 application 01; (h) rule 48 application 01; and (i) design produced after application of rules.

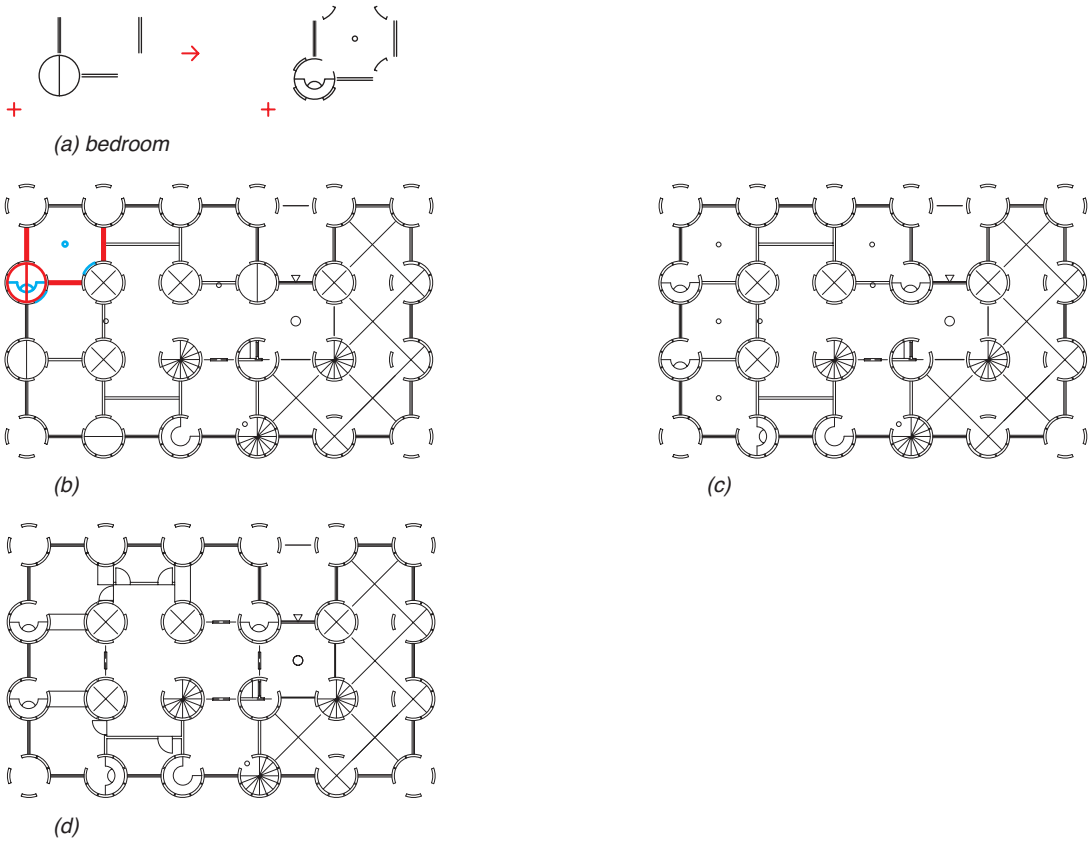


Figure 4.21 Entelechy grammar – Rules to for bedrooms and interior details: (a) rule 49; (b) rule 49 application 01; (c) design produced after four applications of the rule 49; and (d) design produced after further application of interior detail rules 50, 51, 53, 55, 58, 62, and 63 (see Figure 4.26 and Figure 4.27 for more on these rules).

application. This rule should be applied for one match at a time until it no longer applies, which results in the four bedrooms of Entelechy I illustrated in Figure 4.21(c).

The second series of shape rules focused on interior details specify a further level of development to elaborate elements that are key to representing the architectonics of the floor plan (rules 50-63). Though these rules impact the interpretation of the language of Entelechy I, they are primarily representational in nature and for that reason they are

not covered in detail here.[100] Of this subset, rules 50, 51, 53, 55, 58, 62, and 63 are used in the production of Entelechy I to achieve the development of these details in Figure 4.21(d).

The final subset of rules in this stage looks to details at the interior/exterior interface to complete the production of Entelechy I. Rule 64 generates the hearth in a rule that specifies a *LHS* of two adjacent major double-height volumes and a *RHS* that locates a double-height fireplace between them. This rule is illustrated in Figure 4.22(a) and a sample match within the design in progress is shown in Figure 4.22(d). Next, rule 65 (Figure 4.22(b)) produces the library loft with a rule composed of a *LHS* describing a major space marked by a circular label at one corner. When this relationship is found as previewed in Figure 4.22(e), the *RHS* of the rule creates an interior bridge echoed by a balcony that mirrors the library loft on the exterior façade. Lastly, rule 66 (Figure 4.22(c)) develops the front entry with a *LHS* specifying the triangular and circular labels that have marked the entry and a *RHS* that produces the front doors and entry bridge that connect the recessed upper entry to an accessible point of the site where guests can arrive. The single match for this rule is illustrated in Figure 4.22(f). When all three rules are applied, the upper level plan of Entelechy I is complete, as shown in Figure 4.22(g).

Two termination rules, *t1* and *t2*, doublecheck the design generation to end the production process in the Entelechy grammar. Both termination rules address unassigned minor spaces as denoted by any remaining centerlines inscribed in the circles of the plan.

---

[100] To be brief, these rules designate the extended thickening of interior walls as storage spaces between bedrooms (rule 50), doors to access rooms and bathrooms (rules 51-55), more possibilities for thickening storage after doors are resolved (rules 56-57), interior partition details at the entry (rules 58-61),handrails at double-height volumes (rule 62), and hollow column details along the circulation hall (rule 63). The complete set of these interior detailing rules is in Figure 4.25 Figure 4.26Figure 4.25, and Figure 4.27.

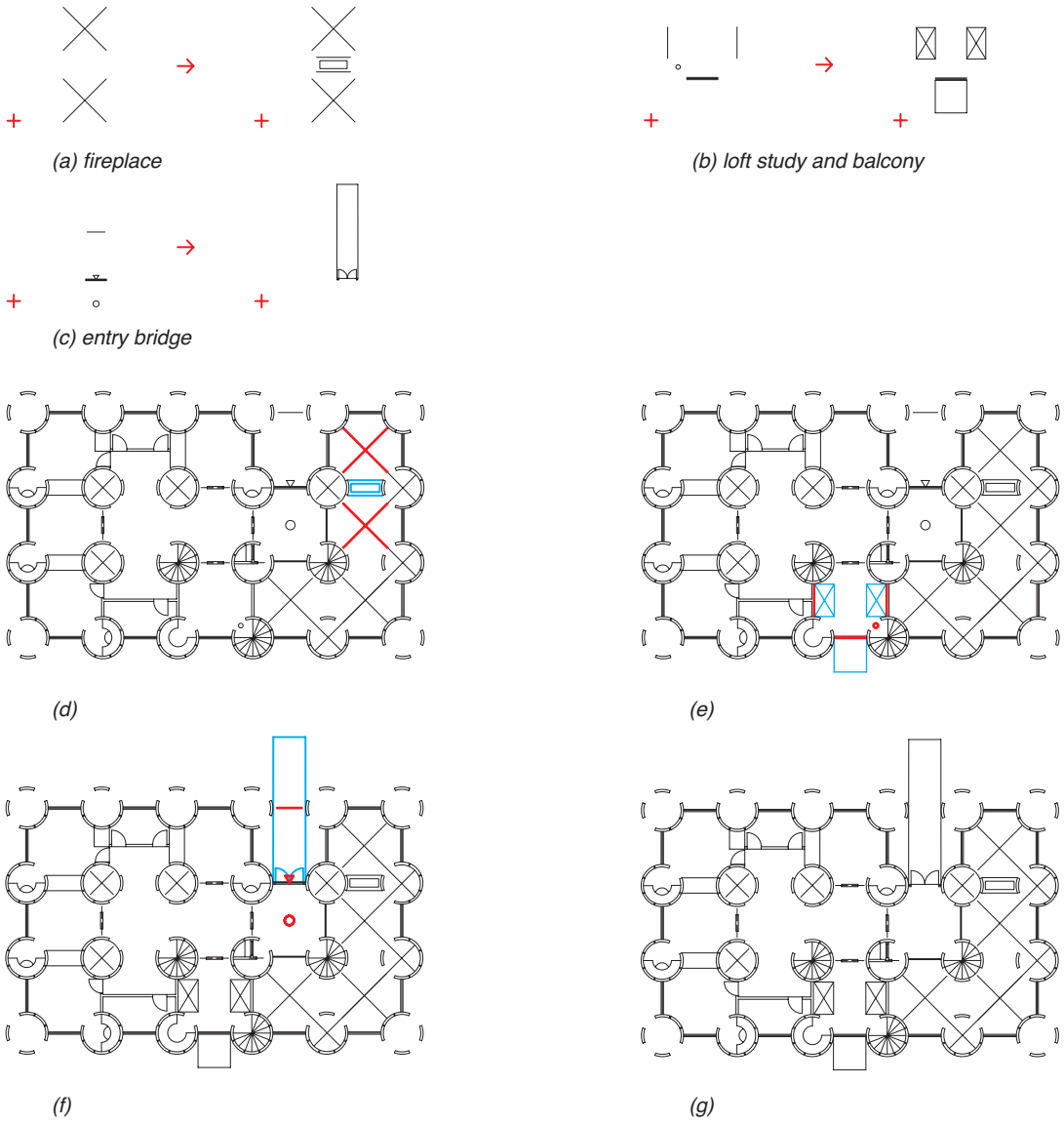


Figure 4.22 Entelechy grammar - Rules 64-66 for interior/exterior details: (a) rule 64; (b) rule 65; (c) rule 66; (d) rule 64 application 01; (e) rule 65 application 01; (f) rule 66 application 01; and (g) design produced after application of rules.

First, rule *t1* allows any of these unassigned spaces along the circulation hall to be opened as a double-height minor volume as denoted by the X-shape inscribed in the circle. Second, rule *t2* does the opposite – removing the label so that the minor space becomes a usable space on the upper piano nobile. These termination rules are both included in Figure 4.27. Once they are applied to a design, all minor spaces will be allocated, resulting

in a complete design characterized by an upper level floor plan.

The rules of stage 3 express the architectonics of the Entelechy grammar. The architectonics of each design produced in the grammar articulate linear walls, curvilinear walls and structure, stairs, and details specific to the interior as well as the interior/exterior threshold. Rules 27, 28, 29, 30, and 31* generate single-lined partitions of a configuration into thickened linear walls of two types: double-lined interior walls and triple-lined glazing at the exterior enclosure. Rules 32, 33, 34, 35*, 36, and 37 address curvilinear walls and structure at the interior, exterior enclosure, and the recessed entry. Rules 38, 39*, 40, 41*, 42*, and 43 locate stairs within hollow columns to provide public, semi-public, and semi-private vertical circulation. Additional uses for minor spaces are assigned in rules 44, 45*, 46, 47, and 48 to define interior details. Rule 49 describes the hybrid major-minor function that characterizes the arrangement of bedrooms within major spaces so that each is allocated with the support of at least one minor space for study or storage. Rules 50, 51, 52*, 53, 54*, 55, 56*, 57*, 58, 59*, 60*, 61*, 62, and 63 develop representational details including storage partitions, doors, handrails, and more to refine the architectonic detail of the plan. Rules 64, 65, and 66 finalize interior/exterior details that extend beyond the enclosure. Lastly, two termination rules, *t1* and *t2*, bring the process to completion to yield an upper level plan.

Of the shape rules in this stage, twenty-seven have been unpacked in detail here to automate the original design for Entelechy I. The remaining rules are denoted above by an asterisk * and are each illustrated in the complete ruleset included in Figure 4.23, Figure 4.24, Figure 4.25, Figure 4.26, and Figure 4.27. Each of these additional rules are interpretations that expand the domestic system established in Entelechy I. The architectonic stage shows how these details in the original house design conform to the

shape rule	*transformation*	*application*
27. walls	*similarity*	*apply all*
28. walls at bath	*similarity*	*apply all*
29. start exterior wall	*similarity*	*apply all*
30. exterior wall	*similarity*	*1x loop all*
31. exterior wall	*similarity*	*apply all*
32. interior columns	*similarity*	*apply all*
33. front columns	*similarity*	*apply all*
34. perimeter columns	*similarity*	*apply all*
35. entry details	*similarity*	*1x*

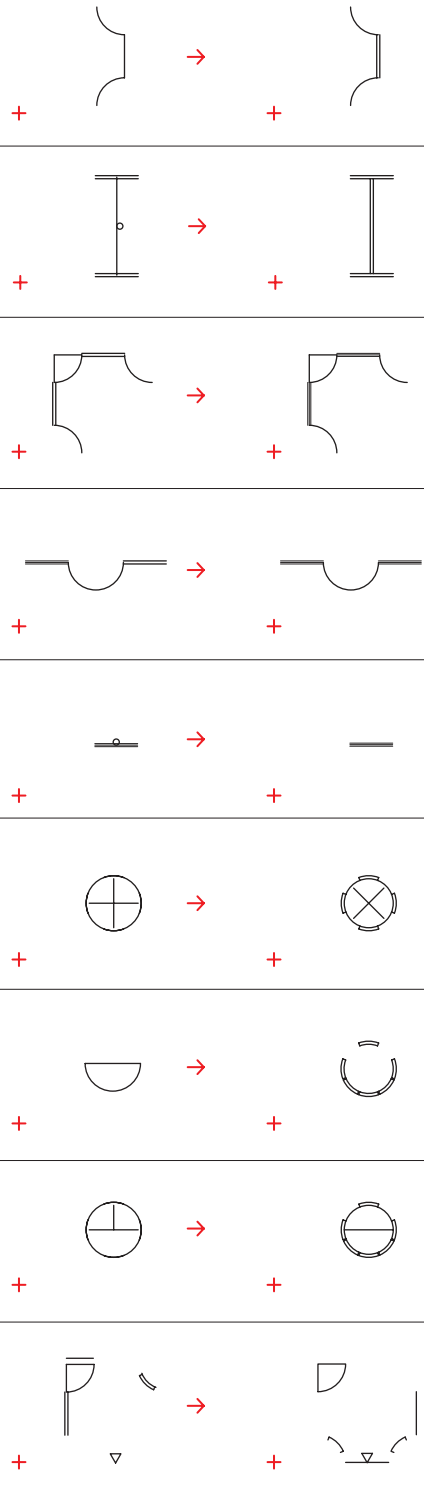


Figure 4.23 Entelechy grammar: Stage 3 rules 27-35.

shape rule	*transformation*	*application*
36. entry details	*similarity*	*1x*
37. corner columns	*similarity*	*apply all*
38. entry stair	*similarity*	*1x*
39. entry stair	*similarity*	*1x*
40. hall stair	*similarity*	*free*
41. hall stair	*similarity*	*free*
42. hall stair	*similarity*	*free*
43. master stair	*similarity*	*1x*
44. perimeter dh	*similarity*	*1x loop all*

Figure 4.24 Entelechy grammar: Stage 3 rules 36-44.

shape rule	*transformation*	*application*
45. foyer closet/bath 	*similarity*	*1x*
46. foyer closet/bath 	*similarity*	*1x*
47. master study 	*similarity*	*1x*
48. entry bedroom 	*similarity*	*apply all*
49. bedroom 	*similarity*	*1x loop all*
50. bedroom storage 	*similarity*	*apply all*
51. bath/room access 	*similarity*	*free*
52. bath/room access 	*similarity*	*free*
53. bath/room access 	*similarity*	*free*

Figure 4.25 Entelechy grammar: Stage 3 rules 45-53.

shape rule	transformation	application
54. bath/room access 	similarity	free
55. bedroom access 	similarity	apply all
56. storage 	similarity	apply all
57. storage 	similarity	apply all
58. entry 	similarity	1x
59. entry x2 	similarity	1x
60. entry 	similarity	1x
61. entry x2 	similarity	1x
62. railing 	similarity	apply all

Figure 4.26 Entelechy grammar: Stage 3 rules 54-62.

shape rule	transformation	application
63. hall details	similarity	free
64. fireplace	similarity	free
65. master balcony	similarity	1x
66. entry bridge	similarity	1x
t1. change label	similarity	free
t2. remove label	similarity	apply all

Figure 4.27 Entelechy grammar: Stage 3 rules 63-66 and termination rules.

geometric system established in the first two stages of the grammar to characterize the framework and configuration of Entelechy I. This is intended to establish how few, if any, architectonic elements are not customized to contribute to the formal composition, reinforcing its flexibility and adaptable interpretations. Additional designs generated by the complete ruleset of the Entelechy grammar will aid in establishing this as discussed in the next section.

4.5 Portm-Inoes

Beyond the production of the upper floor plan of Entelechy I, the implementation of the Entelechy grammar in *Shape Machine* can utilize this same set of rules to produce multiple designs based on the interpretation of the house presented here. The complete ruleset subsequently enlarges this interpretation by adapting the principles encoded in the initial rules to address contexts beyond the demands of the original design. These designs speculate on the possibilities for variation within this recasting of Entelechy I, as given in mechanically produced plans called *Portm-Inoes* to reinforce their reading as a postmodern domestic system. These thirty designs are organized as pairs that demonstrate two variations, each resolved for fifteen underlying structures that range from a 2 x 2 to a 4 x 6 major grid. More precisely, these representative designs cover possibilities for 2 x 2, 2 x 3, 2 x 4, 2 x 5, 2 x 6, 3 x 2, 3 x 3, 3 x 4, 3 x 5, 3 x 6, 4 x 2, 4 x 3, 4 x 4, 4 x 5, and 4 x 6 major grids. This range was chosen to expand and contract around the 3 x 5 major grid of Entelechy I, suggesting the versatility of Portman's housing system and its potential to function for additional domestic programs. At one end of the spectrum, the 2 x 2 is used to satisfy the simplest field condition possible for a one-bedroom, studio, or loft design, while at the other end the 4 x 6 suggests a palatial design with spaces more conducive to congregating and entertaining.

These examples correlate to the setup of Entelechy I with the same parameters for the major and minor grid modules, a similar programmatic basis for single-family tenants, as well as identical considerations for development on a site manipulated to achieve the house entry configuration. Still, the designs offer novel interpretations for the application of these parameters that take on Portman's narrative of the house as a generator of principles with broad implications. And clearly this is just the beginning for a

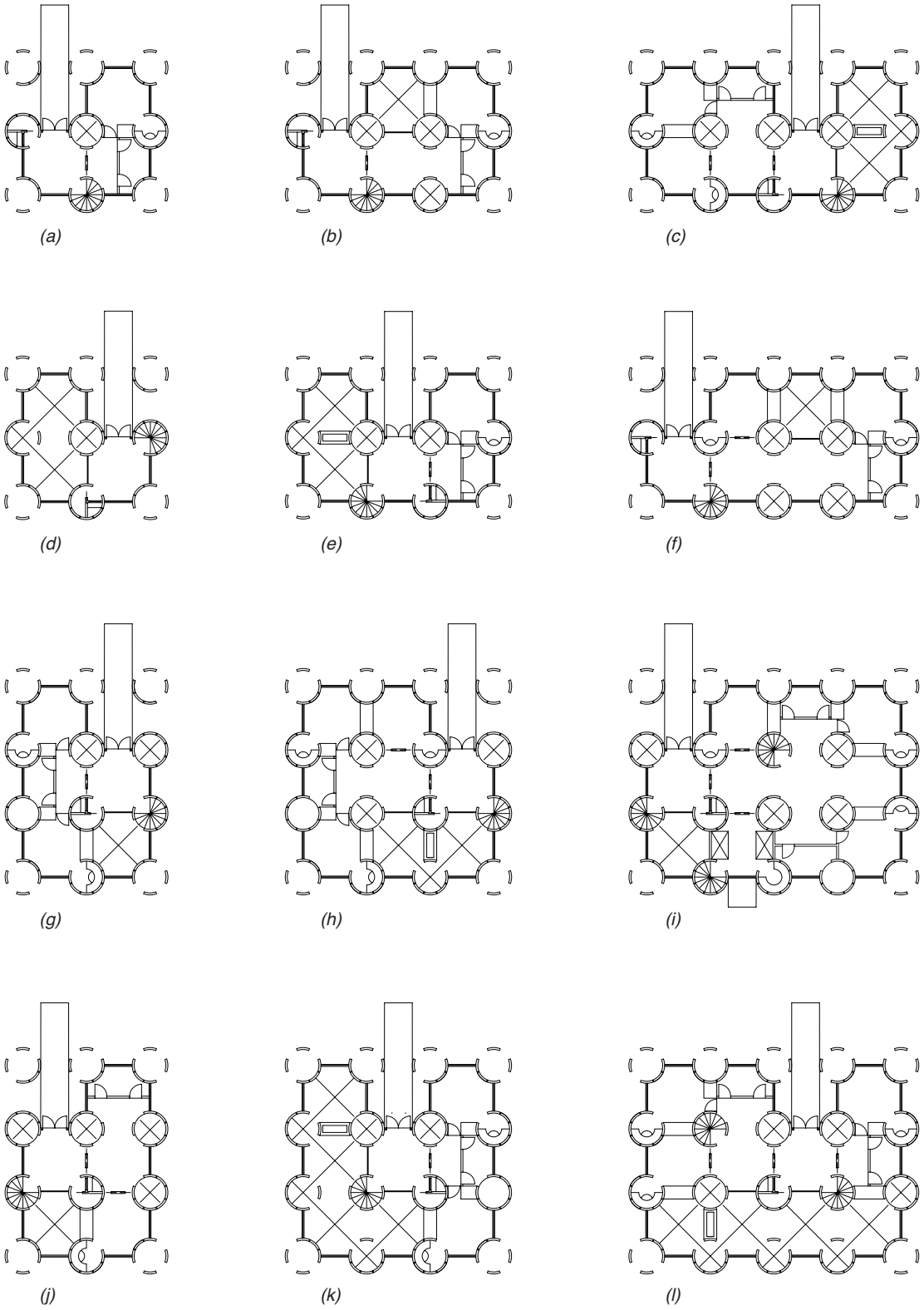


Figure 4.28 Portm-Inoes: sample designs for 2 x 2, 2 x 3, 2 x 4, 3 x 2, 3 x 3, and 3 x 4 grids, each generated in *Shape Machine*.

whole new series of designs and shape rules that can critically engage the findings of the Entelechy grammar – a first take on this front will be given in the next chapter.

The thirty design variations are offered in a series of plans where their individuality can be readily appreciated (Figure 4.28, Figure 4.29, Figure 4.30, and Figure 4.31). Their essential features will be highlighted alongside a more critical summary and assessment of key rules used to generate them. In all, one initial rule, 66 shape rules, and 2 termination rules define the complete ruleset of the Entelechy grammar. These shape rules and the computations in *Shape Machine* that deploy them provide a constructive playground for precisely interpreting the organizing principles embedded in the house.

The rules describe spatial relationships that aim to interpret these principles visually as simplified arrangements that build on each other in stages to structure procedures (algorithms) that generate designs. However, clearly, some of these relations and rules are more significant than others, and in all, their cumulative efforts to produce a formal system that embodies Portman's "space within space" concept is the key theme that emerges from their study (Portman and Barnett, 1976; Portman, 1997). This language is established sequentially in the Entelechy grammar with particular focus on the domestic coordinate unit to conceptually organize the spaces of the house. More precisely, the geometric and spatial concepts that generate Portm-inoes can be conceptualized in relation to five key interests in: a) Platonic rules; b) self-similarity rules; c) figure-ground reversal rules; d) boundary ornamentation rules; e) offset rules; and their combinations.

Platonic rules privilege the use of Platonic forms, for example, the square, the circle, and the regular polygons, as primary geometries in Portm-Inoes. In Entelechy I, square and circle are differentiated and combined in the placement of figures, which is

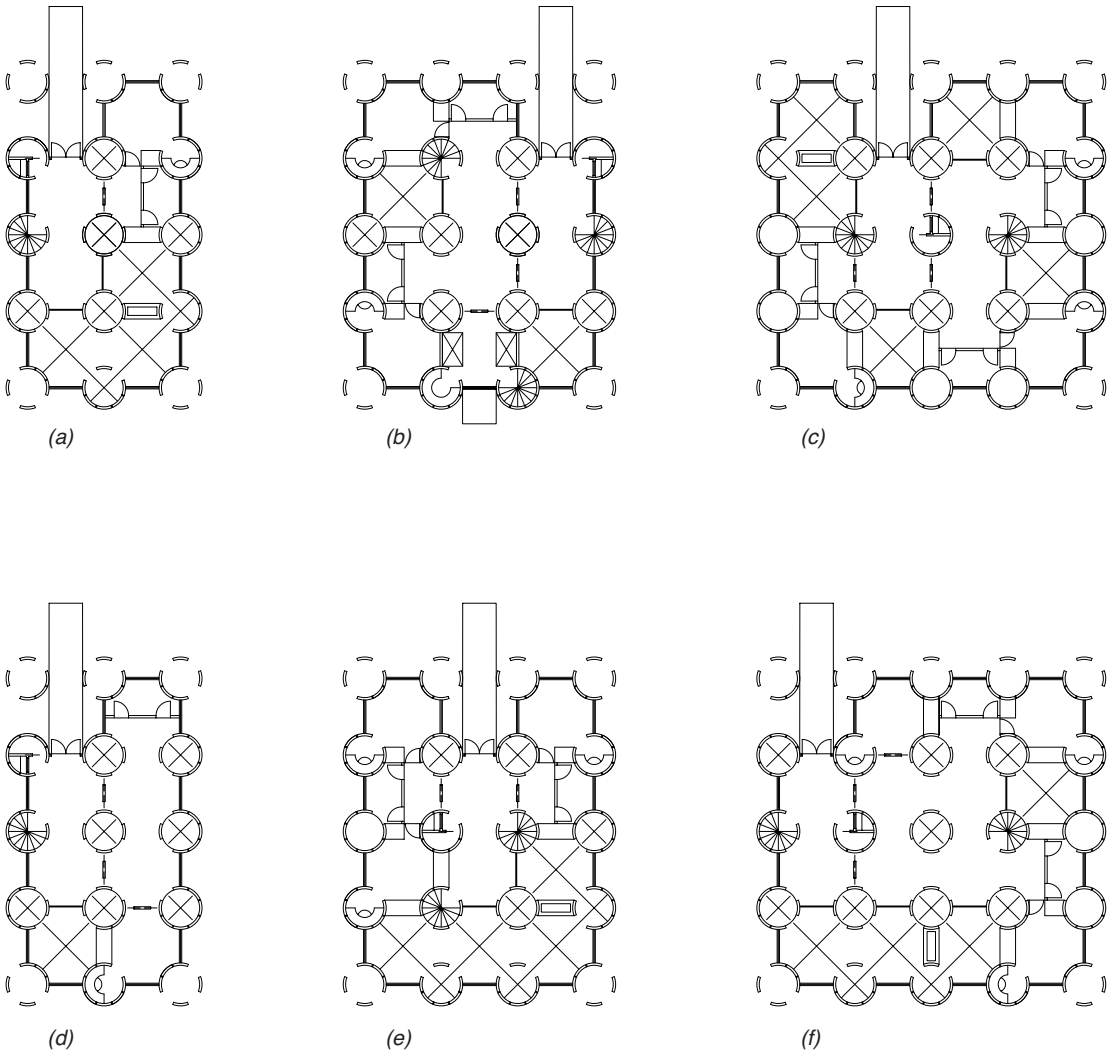


Figure 4.29 Portm-Inoes: sample designs for 4 x 2, 4 x 3, and 4 x 4 grids, each generated in *Shape Machine*.

specified in rule 6 (Figure 4.6). This combination produces a hybrid eight-sided space as a combination of square and circle, as specified in the *LHS* of rule 12(Figure 4.8). These forms, and the circular figures specified at their corners, are foundational in structuring a consistent approach to the spatial organization of major and minor spaces to compose Portman's domestic coordinate unit. This principle reinforces the Platonic geometries of Portm-Inoes as a spatial characteristic carried throughout the domestic system in horizontal and vertical organizations where, for example: a) parts of squares combine with

parts of squares as in rule 16 (Figure 4.10); b) parts of squares combine with parts of circles as in rule 49 (Figure 4.21); and c) parts of circles combine with parts of circles as in rule 43 (Figure 4.19). In Portm-Inoes, these geometries elaborate how Platonic forms are pursued to structure configurations that resist singularity and thrive on reinterpretation, anticipating the use of fundamental shapes and their combinations to define centrally planned interior spaces, as in the Midnight Sun cocktail bar (Figure 3.25) and Atria Hotels (Figure 3.31), as well as master-planned groups of spaces, as in the towers of the Renaissance Center (Figure 3.39) and the pavilions of Entelechy II (Figure 3.44).

Self-similarity rules describe the repetition of modules in Portm-Inoes, an organization deployed in Entelechy I to provide a structure for multiple interpretations of domestic form and function that can scale to interior, hospitality, urban, and other residential designs. Rules 1 (Figure 4.2), 2 (Figure 4.3), and 5 (Figure 4.4) produce the initial layered modularity of the framework that is subsequently the underlying fabric of all of the Portm-Ino iterations. In Entelechy I, the module is essentially multiple so that spaces are nested within other spaces that depend on the same dimensional logic, yielding a self-similar organization. The repetition of these modules is reinterpreted throughout the Portm-Ino system, for example: a) to characterize space as double and single-height volume in rules 20 and 25 (Figure 4.11 and Figure 4.13); b) to define interior and exterior enclosure in rules 27 and 33 (Figure 4.17 and Figure 4.18); c) to specify functions adapted to each module in rules 38 and 49 (Figure 4.19 and Figure 4.21); and more. These rules suggest self-similarity as a concept that can unify a formal organization and offer diverse possibilities for changing, exchanging, and multiplying scales. In the broader corpus, this approach can be seen in the self-similar characteristics of the Atria Hotels (Figure 3.31) as well as in the towers and tower groupings of the Renaissance Center (Figure 3.39).

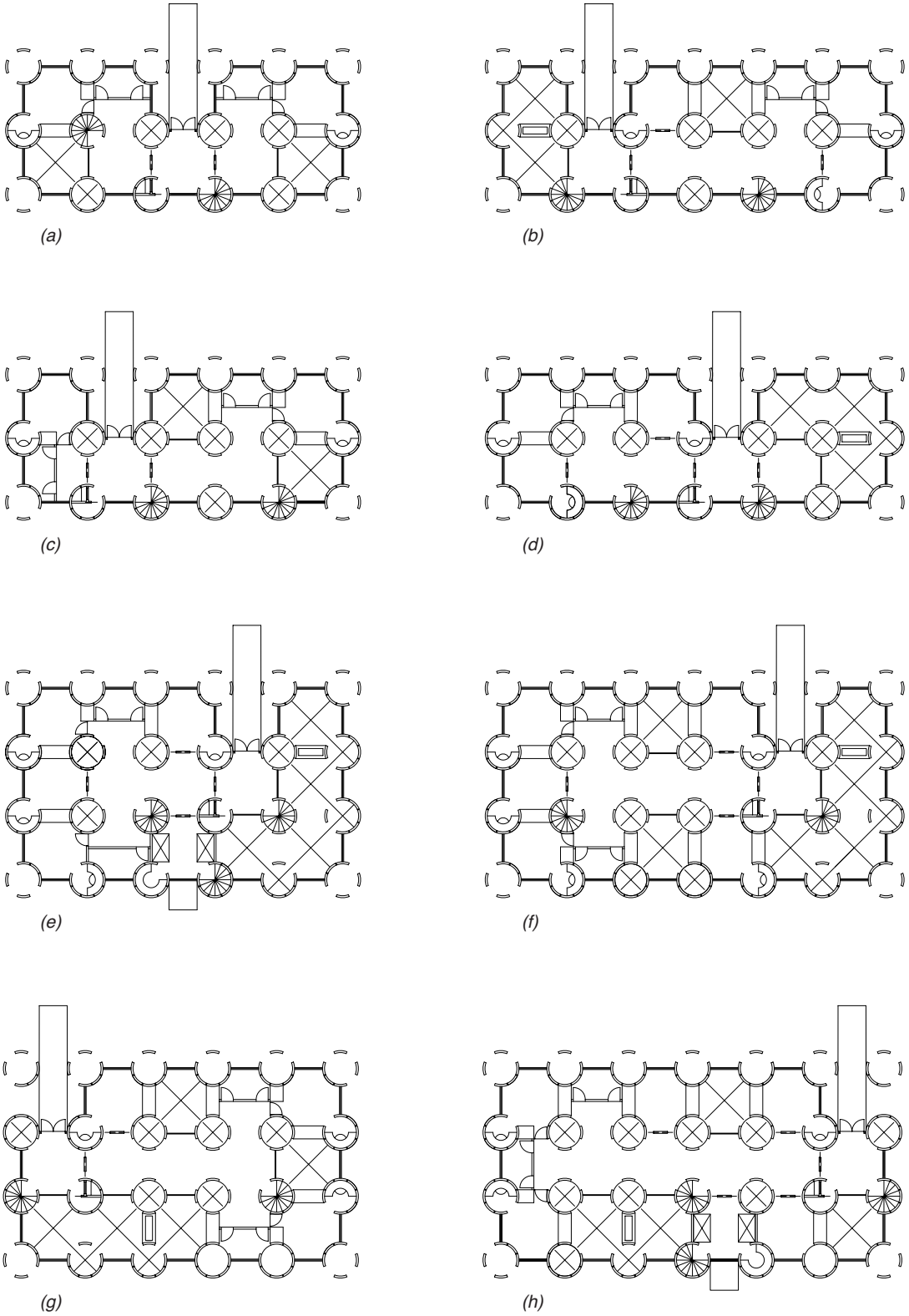


Figure 4.30 Portm-Inoes: sample designs for 2 x 5, 2 x 6, 3 x 5, and 3 x 6 grids, each generated in *Shape Machine*.

Figure-ground reversal rules highlight Portman's interest in figures, and even more in their inversion and substitution, to yield an architecture that is both legible and surprising. In the Entelechy grammar, Platonic rules and self-similarity rules generate the domestic coordinate unit in stages 1 and 2 elaborate how a simple, Platonic vocabulary is pursued to structure self-similar configurations that resist singularity and thrive on reinterpretation and reversal in subsequent rules. These rulesets anticipate the use of figure, ground, and their combinations to define centrally planned interior spaces, as in the Midnight Sun cocktail bar (Figure 3.25) and atria hotels (Figure 3.31), as well as master-planned groups of spaces, as in the towers of the Renaissance Center (Figure 3.39) and the pavilions of Entelechy II (Figure 3.44). In this way, the alternating relations between figure and field yield a system that is recurring *and* reconsiders spatial relations through inversions that exchange background organizations as foreground features and vice versa. In Portm-Inoes, a half-bathroom is rendered as an occupiable, sculptural figure (rule 46; Figure 4.20) and alternatively as a hollow, perforated stair enclosure (rule 40; Figure 4.19), foreshadowing repetition and reversals in Portman's other works – for example from the solid hotel to the open atrium (Figure 3.29) or from the hidden elevator core to its exposure as a kinetic sculpture (Figure 3.34).

Boundary ornamentation rules foreground Portman's rhythmic approach to subdivisions that resist clear definitions precisely through more intricate and exaggerated articulations as edges, corners, and thresholds. What starts as a rigid major-minor framework in the generation of Entelechy I is dissolved by connections that reframe the boundary condition of the domestic coordinate unit as a perforated one for unifying spaces, beginning at the recessed entry condition and the entry sequence that follows. This sequence, produced with rules 12 (Figure 4.8), 13, and 15 (Figure 4.9) to characterize

Entelechy I, is present in all Portm-Inoes so that an entry axis is carried through a design to organize circulation and movement. Building on this, the secondary cross-axis of a design extends connection by concatenating spaces on the interior to produce versatile circulation halls. These halls express emergent L-shapes (Figure 4.28(c), (j), and (l); Figure 4.29(a); Figure 4.30(b), (c), and (d)); cross-shapes (Figure 4.28(i) and Figure 4.31(a)); T-shapes (Figure 4.29(a); and Figure 4.30(e), (f), (g), and (h)); and bilaterally-symmetrical U-shapes (Figure 4.30(a)). In addition, larger Portm-Inoes have grander halls that can be composed to define rotational symmetries too (Figure 4.29(c)). At the exterior, perimeter boundaries undulate in all Portm-Inoes with a characteristic linear-curvilinear sequence at the enclosure (established in rules 29, 30, 33, 34, and 37 (Figure 4.17 and Figure 4.18)) to define a rhythm that breaks down the strict demarcation of interior and exterior spaces. This is specifically accomplished by defining corners that are rendered for a variety of formal relations and functions, for example as: a) fully interior spaces in rule 32 (Figure 4.18(a)); b) perimeter spaces that open to the exterior and subtract from the interior in rule 33 (Figure 4.18(b)); c) perimeter spaces that add to the interior in rule 34 (Figure 4.18(c)); and corner spaces that are fully exterior in rule 37 (Figure 4.18(e)). This reinterpretation of boundary established in Entelechy I and revisited in the Portm-Inoes is a precursor to the characteristic interior-exterior features of Portman's architecture that results in an ambiguous sense of exterior, urban-like spaces in a hotel interior (Figure 3.32) and interior, room-like spaces in an urban exterior (Figure 3.39).

Offset rules emphasize the thickening of dimensions and profiles – in both solid elements and void spaces – to interpret Portman's approach to volumes that characterize plan organizations. This concept is most clearly defined as an offset in the definition of interior, hollow columns in rule 32 (Figure 4.18). In addition, the definition of larger voids

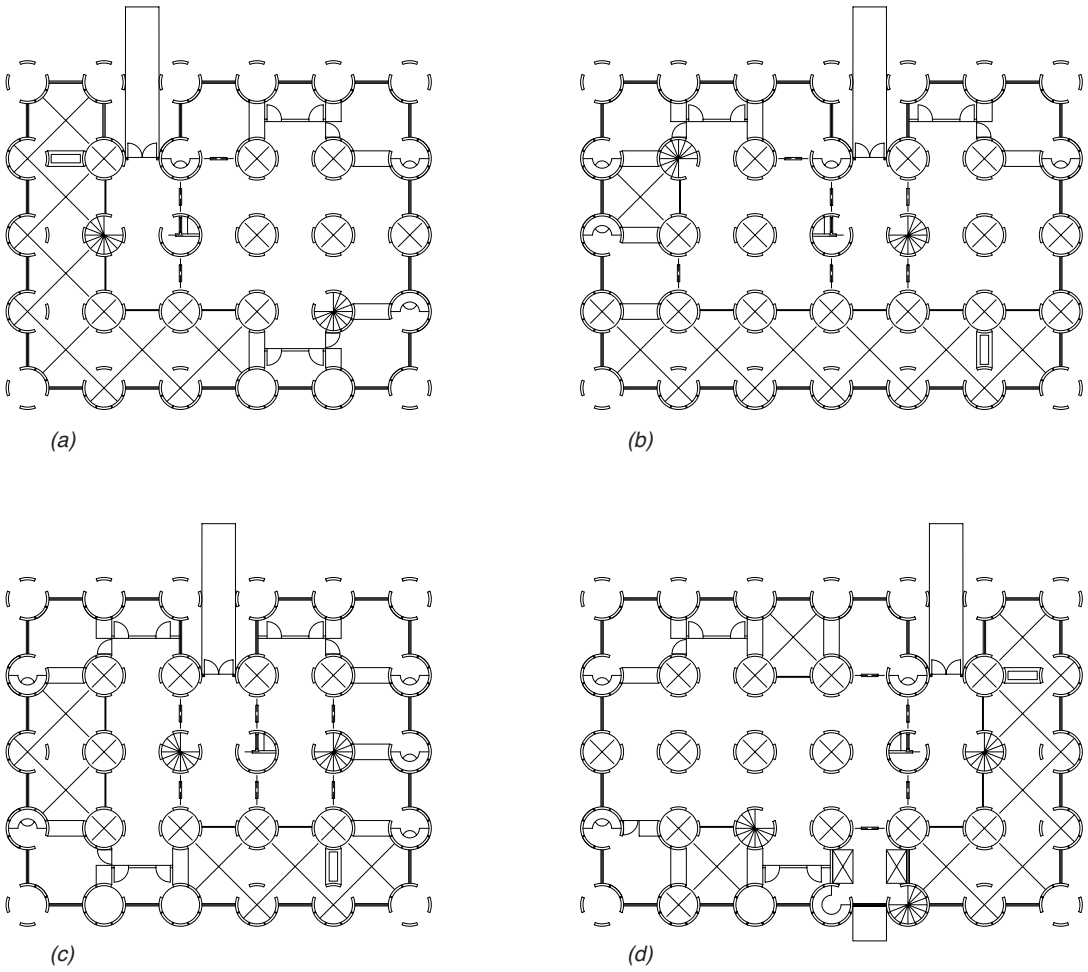


Figure 4.31 Portm-Inoes: sample designs for 4 x 5 and 4 x 6 grids, each generated in *Shape Machine*.

is constrained by the development of architectonic solids generated as offset forms directly from the major-minor framework (see rules 27-37 of the architectonic stage, depicted in Figure 4.17 and Figure 4.18). These volumes demarcate the social division of public and private space in a design, as specified in rules 20 (Figure 4.11), 21, 22 (Figure 4.12), and 25 (Figure 4.13). In the original Entelechy I design, this results in double-height entertaining spaces that are entirely separate from single-height family spaces (Figure 4.30(e)). Portm-Inoes that emulate this include Figure 4.28(c), (e), (g), (i), (j), and (k); and Figure 4.30(d). Alternatively, volumes can be arranged to compose precise interior and/or

exterior relationships that are more freely arranged with overlapping social boundaries. For example, for sites with a desirable view to the backyard, double-height volumes can be arranged along the backside with the upper circulation hall overlooking layers of interior and exterior space as in the designs of Figure 4.28(l); Figure 4.29(e); or Figure 4.31(b). More ambitiously, the weaving of the single-height circulation hall with double-height volumes can result in interior bridges connecting views across the interior/exterior as in the Portm-Inoes of Figure 4.30(f) and (g). And more idiosyncratic arrangements are possible too, allowing for unique connections to be made as in the designs of Figure 4.29(b), (c), and (f); Figure 4.30(c) and (h); and Figure 4.31**Error! Reference source not found.**(c) and (d). In all cases, the grander, major volumetric expression is echoed by the atmospheric volume defined by the interior columns that perforate the depth of a Portm-Ino design with cylindrical offset forms that channel natural light from above. The definition of these voids is explored at a monumental scale in the offset forms of the atria hotels (Figure 3.36).

In all, these geometric and spatial concepts are an interpretation designed to demonstrate the potential of the Portm-Ino as an emblem of postmodern reinvention that can readily correspond to the modernist Dom-Ino, as proposed in chapter 3. The Portm-Inoes are proof of the possibilities of this rule-based interpretation of Entelechy I and the outcomes the Entelechy grammar can generate to formalize another way of looking at Portman's architecture. But the house is also proposed as a machine, not for living as in Corbusier's proposal (1927), but for generating design possibilities that exceed their initial residential context. The process to map the concepts in the house to other arrangements in Portman's corpus is not as straightforward as the project to develop Portm-Inoes – it requires identity, transformation, and reconstruction. Shape rules that describe these

transformations and adaptations can be further redefined with transformation grammars and rule schemata that suggest how these concepts can continue to yield designs by interpreting Portman's architecture through the lens of Entelechy I. The rule-based argument thus proposes Portman's architecture as algorithmic, not just in the developer-driven aspects of their calculations, but in the formal moves that relate the larger body of work. The relations between Entelechy I and the larger corpus, as well as how the five concepts demonstrated in shape rules specific to the house evolve in other contexts will be unpacked in the next chapter.

4.6 Summary

The focus here on Entelechy I (1964, Atlanta, GA, USA) provides another way to study John Portman's architecture. Portman was not known for single-family domestic work, still it was in his residence that he continually found reference to his other works (Portman and Barnett, 1976; Portman, 1997). Research on the house in the Entelechy grammar inquires on how revisiting the design can reframe Portman's work in a novel way to interpret his designs through formal, visual computations. More specifically, the project here addresses this ambition by designing a software implemented in *Shape Machine for Rhino* to automate design variations that demonstrate how Entelechy I can be parsed as a generative system for housing design.

The work in this study lays the groundwork for new comparisons to be made by critically and creatively revisiting the logic of the house. These studies are the subject of the following chapter, where a collection of Portman's works is elaborated in a rule-based theory that builds on the Entelechy grammar to relate a wider sampling of designs. The principles proposed here will be further interpreted in shape rules and schemata in the

Portman variations to describe the lessons of the house as a comprehensive, systematic, and adaptable design effort.

CHAPTER 5. THE PORTMAN VARIATIONS

Chapter 5 builds on the interpretation described in the Entelechy grammar to propose how the design philosophy embedded in Entelechy I can be viewed as a productive resource for understanding a larger cross-section of Portman's works. This is achieved mechanically in *Shape Machine* to decipher formal relations between the design of the house and a broader corpus. These findings verify intuitions on Portman's language in a machinic way that enlivens possible interpretations, providing new ways to see these works and their overlapping relations as an ongoing project. Critically, this notion of language in Portman's corpus has been decomposed to categorize tropes in his architecture (Cohen, 2017) or the eccentricities of popularity, pizzazz, and spectacle (Goldberg, 1974; Lapidus, 1978; Sorkin, 1991; Bonner, 2017). Alternatively, the project here engages Portman's narrative through rule-based composition to interpret how organization and geometry dovetail in "principles that work for a room or a restaurant, a building or a group of buildings" (Portman and Barnett, 1976).

The chapter is organized to address the remaining corpus introduced in chapter 3, which includes designs for the Midnight Sun Cocktail Bar (1968), the Hyatt Regency Atlanta (1967), the Hyatt Regency O'Hare (1971), the Marriott Marquis Times Square (1985), the Detroit Renaissance Center (1976), and Entelechy II (1986). These works, all completed after Entelechy I (1964), illustrate how spatial relationships translate from the house to four other contexts to demonstrate a versatile interpretation of Portman's architectural language. These contexts include interior, hospitality, urban, and residential designs to propose how organizational principles in Entelechy I are reworked to construct a narrative of potential adaptation and reuse in actual forms from the existing corpus.

5.1 Introduction

The goal of this chapter is to build on the lessons of the Entelechy grammar to take on the subject of Entelechy I as an ongoing resource with generative influence in Portman's subsequent works. To do this, a combination of identity rules (Stiny, 1996), transformation rules (Knight, 1994; 2014), and additional shape rules are utilized to bridge between Entelechy I and a series of other designs through transformation grammars[101] specified by schematic rulesets that aim to capture spatial relationships as conceptual and viable proof of the argument. Four transformation grammars are proposed: a) the Midnight Sun grammar; b) the Atrium Hotel grammar; c) the Renaissance Center grammar; and d) the Entelechy II grammar. Each transformation grammar includes three stages: a) an *identity* stage that relates the new context to Entelechy I; b) a *transformation* stage that translates an organizational structure from Entelechy I to the new context; and c) a *reconstruction* stage that customizes the structure to develop conceptual designs that match the existing corpus.

[101] Knight (1994; 2014) extends the notion of a shape grammar through transformation grammars to model theories of stylistic change in a precise and generative way. Transformation grammars address more than one architectural language, aiming to explain how one language can be translated into another through rule transformations formalized by rule addition, rule deletion, and/or rule change. Knight demonstrates this approach by modeling a shape grammar for Frank Lloyd Wright's Usonian houses that builds on the same compositional structure as Koning and Eizenberg's (1981) grammar for Wright's prairie-style grammar. Rule transformations from one shape grammar to a new transformed grammar are thus used to visually study the evolution of spatial relationships from the prairie corpus of expansive "butterfly" compositions to the Usonian corpus of L-shaped "tadpole" designs (Knight, 1983; 1994). Alternative approaches to transformations in shape grammars use transformation rules, which are distinguished from rule transformations in how they apply directly to designs, rather than as translations between separate shape grammars (Knight, 2014). Examples of transformation rules are given in two studies that produce new house designs in relation to a vernacular corpus, blurring the boundaries between analytic and synthetic modes of description. Colakoglu (2001; 2005) constructs transformation rules that maintain core spatial features of a vernacular housing corpus while allowing for the modification of other aspects so that contemporary features can be introduced in new designs that simultaneously blend in historic neighborhoods, much like the aspirations of Flemming's Queen Anne grammar (1987). Eloy and Duarte (2011) propose transformation rules for adaptation to generate new designs within a corpus of existing, historic building layouts.

The transformation grammars focus on a condensed development of spatial relations between Entelechy I and each context of the corpus, while a sample catalog of possible variations is given to demonstrate a wider design potential that inevitably involves more shape rules not included in the present discussion in order to maintain conceptual clarity. Additional description of the identity, transformation, and reconstruction rules as schemata (Stiny, 2006; 2011; Economou and Kotsopoulos, 2014) is offered to help read between the lines of the conceptual figures produced in transformation grammars and the expressive figures cataloged as variations.[102]

Shape rule schemata are used in this research to logically reconceptualize shape rules, so that multiple contexts and variations can be developed. This is achieved by pairing shape rules with companion schemata that interpret the logic of each shape rule for a more general purpose and appropriation. A set of initial schemata are introduced here, and they can be easily multiplied to many more by defining their inverses as well as combining them in compound schema with additional operators to generate sums and products (Stiny, 2011), which will be demonstrated in the transformation grammars that follow. For now, the initial seven shape rule schemata include:

$x \rightarrow x$ *identities*

[102] A shape rule schema is a convention for the logical description of a shape rule that allows for shape substitutions and further exploration of the relational possibilities of a rule in other contexts. The schema foregrounds logic so that a rule can be generalized, simplified, and applied for any shape predicate acting as an assignment to the schema. The original definition of the shape rule schema was particularized by shape-specific parameters, so that parametric shape rules could be specified. In this way, values could be assigned to variables within a shape definition for a parametric shape rule (Stiny, 1977). More recently, the schema has been extended to accommodate a shape assignment rather than a real value assignment, so that any parametric shape can be visually assigned to any schema to generate a parametric shape rule (Stiny, 2006; 2011). This redefinition of the schema opens research in shape grammars up to a variety of new ways to describe, interpret, evaluate, adapt, and reuse shape rules via schemata (Stiny, 2011; Economou and Kotsopoulos, 2014; Ligler and Economou, 2019a).

$x \rightarrow y$	*unrestricted replacement rules*
$x \rightarrow t(x)$	*Euclidean transformations*
$x \rightarrow b(x)$	*boundary rules*
$x \rightarrow prt(x)$	*parts*
$x \rightarrow$	*erasing rules*
$\rightarrow$	*empty rule*

More specifically: a) $x \rightarrow x$ is a schema to describe an identity rule used to search and identify the same shape, *x*; b) $x \rightarrow y$ is a schema to describe a general replacement rule, where a shape, *x*, is replaced by another shape, *y*; c) $x \rightarrow t(x)$ is a schema to describe Euclidean transformations, where a shape, *x*, is transformed by a translation, rotation, reflection, or scaling, as described by the operator, *t*; d) $x \rightarrow b(x)$ is a schema to describe a boundary rule, where a shape, x, is redescribed by its boundaries, as defined by the operator, *b*; e) $x \rightarrow prt(x)$ is a schema to specify a part, *prt*, of a shape, *x*; f) $x \rightarrow$ is a schema for erasing, so that a shape, *x*, is removed from a design; and g) $\rightarrow$ is an empty rule, conveying the technical device of the arrow and its role in defining a design action.[103]

The discussion of specific rules and schemata in the transformation grammars provides understanding as to how reworked rulesets might be further designed to produce variations as well as to adapt beyond the corpus presented here to address other

[103] The technical preliminaries of shape rules and their alternative definition as schemata are well established in the literature and more thorough introductions to their specifications, conventions, and more can be found in a number of sources (see, for example: Stiny, 1980a; 1986; 2006; 2011; Knight, 1994; Krstic, 2001; Krstic, 2005; Economou and Kotsopoulos, 2014). These technicalities are offered to lay the groundwork for a more in-depth discussion of specific shape rules and schemata as defined in the transformation grammars specified here.

emblematic works, including those of Portman and beyond. This strategy is not unlike an earlier study on the atrium hotel in relation to Entelechy I (Ligler and Economou, 2019a), with the exception being that all of the computations, conceptual designs, and variations presented here are produced in *Shape Machine* to verify the calculations and outcomes.

The identity rules that initiate the process for each transformation grammar fall into two broad categories, each identifying key spatial relations from Entelechy I that translate to other organizations across the corpus. The first, which maps to interior and hospitality designs at the Midnight Sun and atrium hotels, focuses on the hollow column's conceptual basis as an organizing figure that provides insight for a room, a restaurant, or a building as a dense, centrally planned configuration. The second, which maps to urban and residential designs at the Renaissance Center and Entelechy II, focuses on the domestic coordinate unit as a conceptual formal structure to inform the expansive and repetitive composition of a group of forms, whether buildings, pavilions, or the major and minor spaces of the original house.

These identities unify the four transformation grammars, the designs of the corpus, and the possible design variations projected in this chapter in their relation to Entelechy I, a correlation that provides a foundation for defining principles of Portman's architectural language. The five concepts introduced in chapter 4 are revisited here to further describe the formal moves that relate the larger body of work and its interest in: a) *Platonic geometries*; b) *self-similarity*; c) *figure-ground reversal; d) boundary ornamentation*; and d) *offset forms*. Contextualizing these actions in relation to the shape rules and schemata of each transformation grammar provides a visual and logical counterpart to each principle, to speculate on how Portman's goal to understand architecture as a "living organism" (1997) can be understood as an ongoing pursuit.

5.2 The Midnight Sun Grammar

Portman's 1968 design for the Midnight Sun Cocktail Bar (Figure 3.25) is the basis for the Midnight Sun grammar, a transformation grammar that theorizes how designs for a room or a restaurant relate to the organizational structure of Entelechy I. The Midnight Sun grammar consists of three stages designed to identify, transform, and reconstruct a conceptual ruleset that maps from the house to the cocktail bar design.

To establish this, an initial identity stage begins the process. This stage consists of a single shape rule to establish an identity between the cocktail bar and Entelechy I. Specifically, this rule is applied to identify and extract the conceptual rendering of the circular minor figure centered at the intersection of four major modules (see Figure 4.7(a)), a relationship that is critical to the definition of the hollow column in Entelechy I. This shape is identified and interpreted here as an underlying basis for transformations between the house and the bar interior. The identity rule utilized to achieve this is shown in Figure 5.1. Another way to describe this rule is in how it operates under the schema $x \rightarrow x$, where x is any shape, allowing for the visual specification of any part a designer might see, search, or select to initiate a production. Once the figure is specified and defined as the basis for a larger narrative relating house and bar, a transformation stage is applied to recalibrate the organization of the figure for the new context.

Figure 5.1 Midnight Sun grammar - Identity rule.

The transformation stage consists of three shape rules, each designed to develop the circular figure by scaling, rotating, and redefining its boundary articulations. Transformation rule 1 (Figure 5.2(a)) is a scaling rule to modify the diameter of the original figure in the house (the initial shape in Figure 5.2(b)) to a new diameter for the cocktail bar. This rule operates under the schema $x \rightarrow t(x)$, where t is a scalar transformation which could be resized for any context by drawing a different *RHS* of the shape rule. A preview of the application of this rule, given in Figure 5.2(c), illustrates the spatial relationship between the residential figure and its expansion to address a commercial interior.[104] When the rule is applied, the resulting design of Figure 5.2(d) is produced to describe a four-part subdivision of a centrally organized interior space. Transformation rule 2 (Figure 5.3(a)) is then applied to this shape (Figure 5.3(b)) to rotate the design to match the orientation of

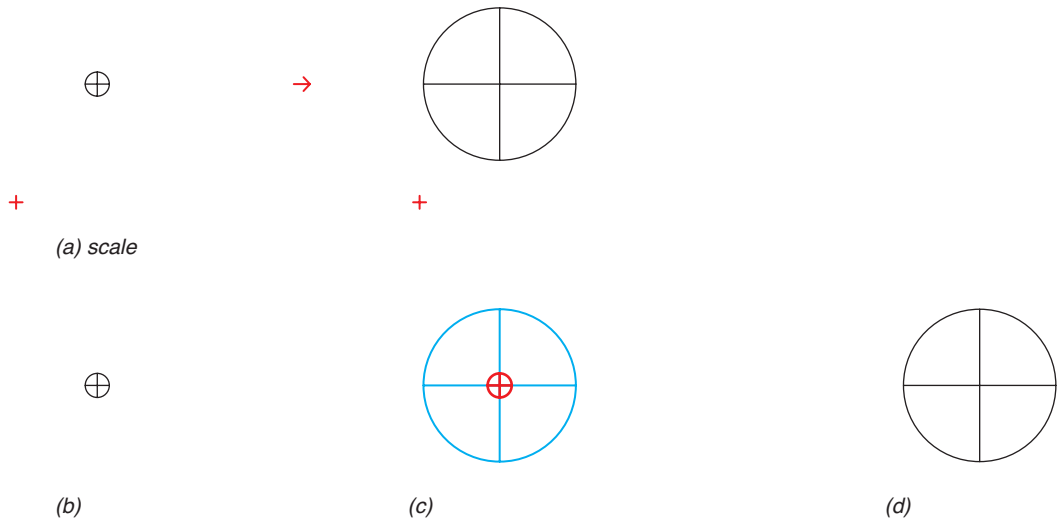


Figure 5.2 Midnight Sun grammar - transformation rule 1: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

[104] The figures in this chapter use the same conventions as in the previous chapter, with a red highlight signifying a match of the *LHS* shape in *Shape Machine* and a blue highlight previewing the application of a rule in terms of the *RHS* shape of each respective rule.

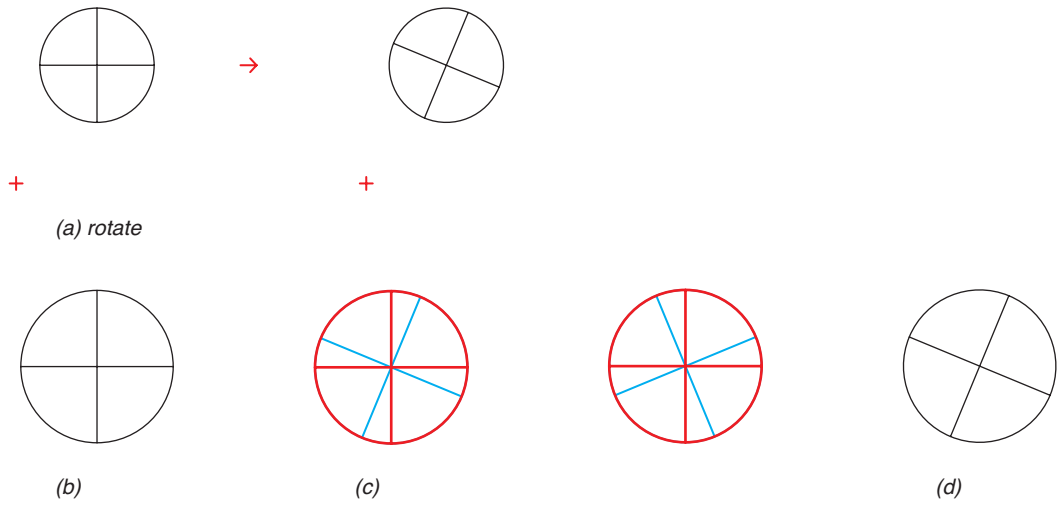


Figure 5.3 Midnight Sun grammar - transformation rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after one application.

the Midnight Sun cocktail bar (Figure 3.25). This rule also operates under the schema *x* → *t(x)*, but in this case *t* is a rotational transformation of twenty-two and a half degrees. This rule could be modified for any rotation by redrafting the *RHS* of the shape rule to address a different orientation. The application of transformation rule 2 produces two results, shown in Figure 5.3(c). When the first match is applied, the shape shown in Figure 5.3(d) is generated to continue the production of the Midnight Sun design.

To complete the transformation stage, transformation rule 3 (Figure 5.4(a)) redefines the boundary articulation of the design. This rule operates under the schema *x* → *prt(x) + y* to describe the selection of a part of the *LHS* shape, *prt(x)*, plus the addition of a new shape, *y*, in the design. More formally, the rule allows the four-part boundary subdivision of the original shape identified in the circular figure (Figure 5.4(b)) to be modified to establish a sixteen-part subdivision for the cocktail bar interior. This rule could be modified for any further subdivision by redrafting the *RHS* of the shape rule to address a different rhythm, which is not just a formality but becomes significant for the introduction

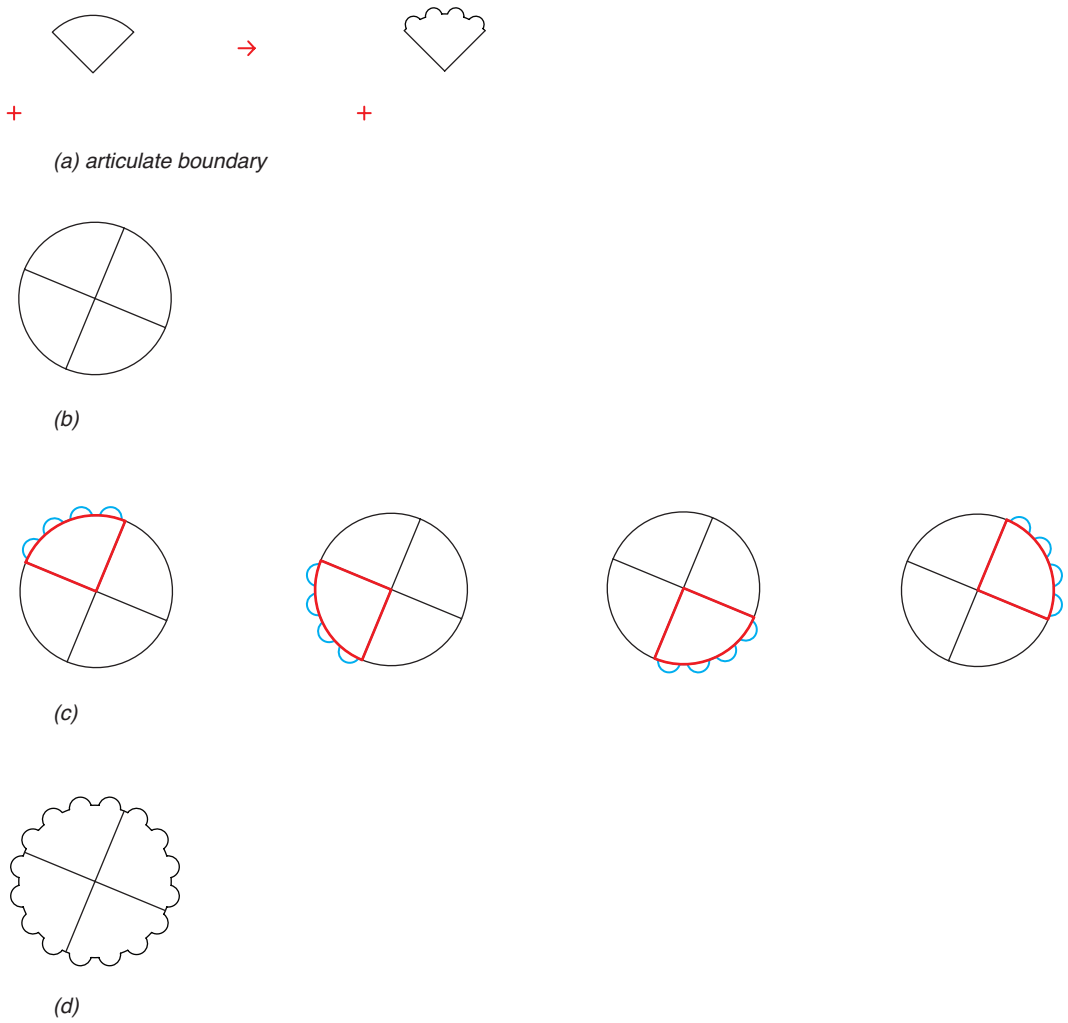


Figure 5.4 Midnight Sun grammar - transformation rule 3: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

of scaled seating and circulation zones in the bar design with subsequent shape rules in the next stage of the transformation grammar. The application of transformation rule 3 produces four matches, shown in Figure 5.4(c). When all four matches are applied in parallel, the design of Figure 5.4(d) is the result of the computation. This shape is the transformed shape used for the conceptual development of the Midnight Sun cocktail bar in the stage that follows.

The reconstruction stage includes four shape rules that redefine the organizational structure produced in the transformation stage to address the seating, thresholds, and central bar of the Midnight Sun design. Reconstruction rule 1 (Figure 5.5(a)) is a replacement rule described by the schema *x* → *y* to generate the elongated banquette seating to correspond to the four-part structure originated in the hollow column of Entelechy I. This shape rule could be rewritten for any replacement desired to explore how

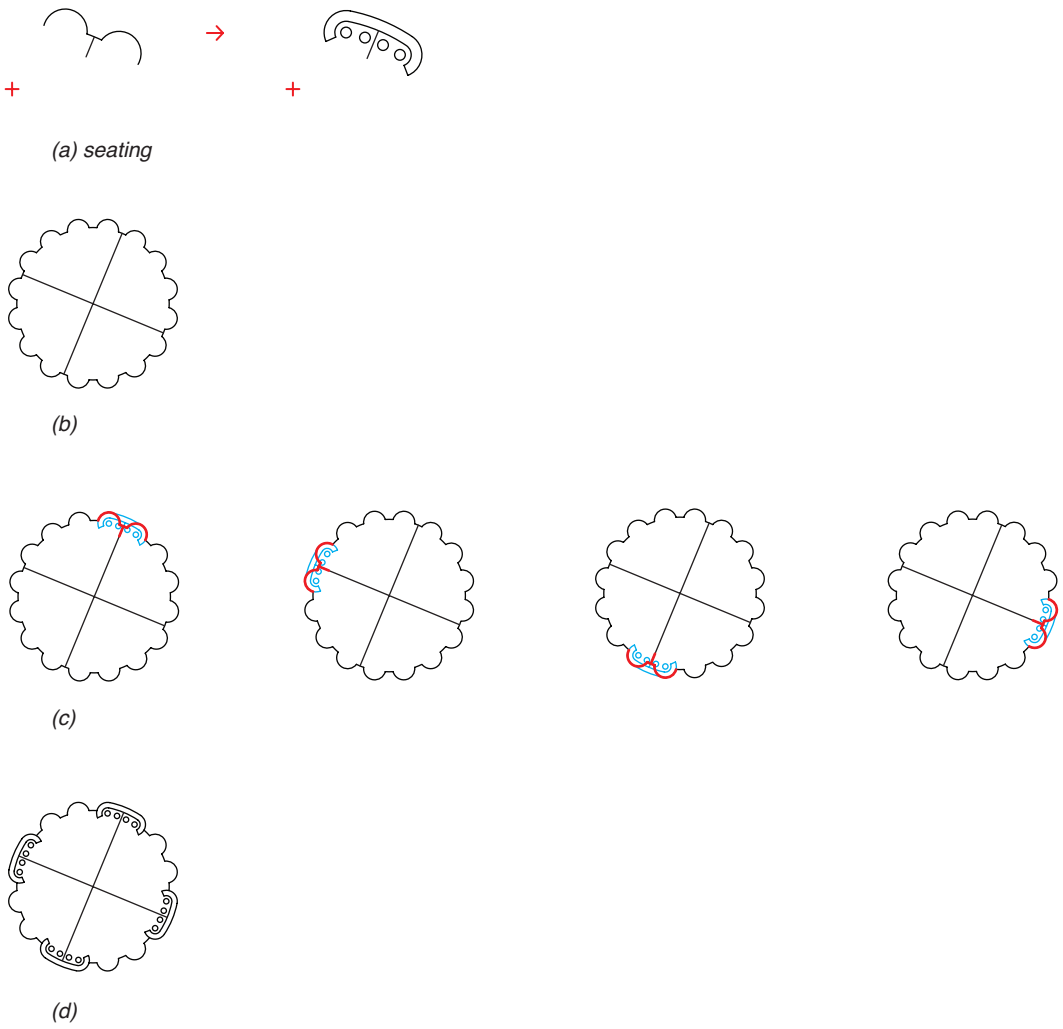


Figure 5.5 Midnight Sun grammar - reconstruction rule 1: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

the underlying four-part arrangement could adapt under different constraints. The application of reconstruction rule 1 to the shape shown in Figure 5.5(b) generates four matches, illustrated in Figure 5.5(c). To generate the original design of the Midnight Sun, all four matches are applied in parallel to produce the shape given in Figure 5.5(d).

Reconstruction rule 2 (Figure 5.6(a)) is then applied to continue the generation process. This shape rule is also a replacement rule to produce seating options for the cocktail bar and is described by the schema $x \rightarrow y$, corresponding to the secondary subdivision of the design in sixteen parts. When reconstruction rule 2 is applied to the shape in Figure 5.6(b), it generates a pair of single tables with curvilinear banquette seating scaled to match the division of the boundary in sixteen parts. This rule clearly illustrates how the cocktail bar furnishings around the perimeter of the interior are essentially a repeating offset of the boundary subdivision, reiterating possible interpretations of rules that offset forms. The application of this rule produces four matches as shown in Figure 5.6(c). One application of this seating arrangement is found in the original Midnight Sun design, the third possibility from the left depicted in Figure 5.6(c). When this selection is applied, the design of Figure 5.6(d) is generated.

A third replacement rule for the boundary seating is given in reconstruction rule 3 (Figure 5.7(a)), which applies to the same *LHS* context as reconstruction rule 2. However, this rule is used to provide a combination of seating and circulation access to the central bar interior. This reversal and exchange between figural seating and open threshold speaks to another take on rules that reverse figure-ground relations, as explored in the arrangement of the cocktail bar. This shape rule is also described with the schema $x \rightarrow y$ and demonstrates how this schema allows for different substitutions by comparison with the previous rules. Given the symmetry of this rule and the available positions in the design

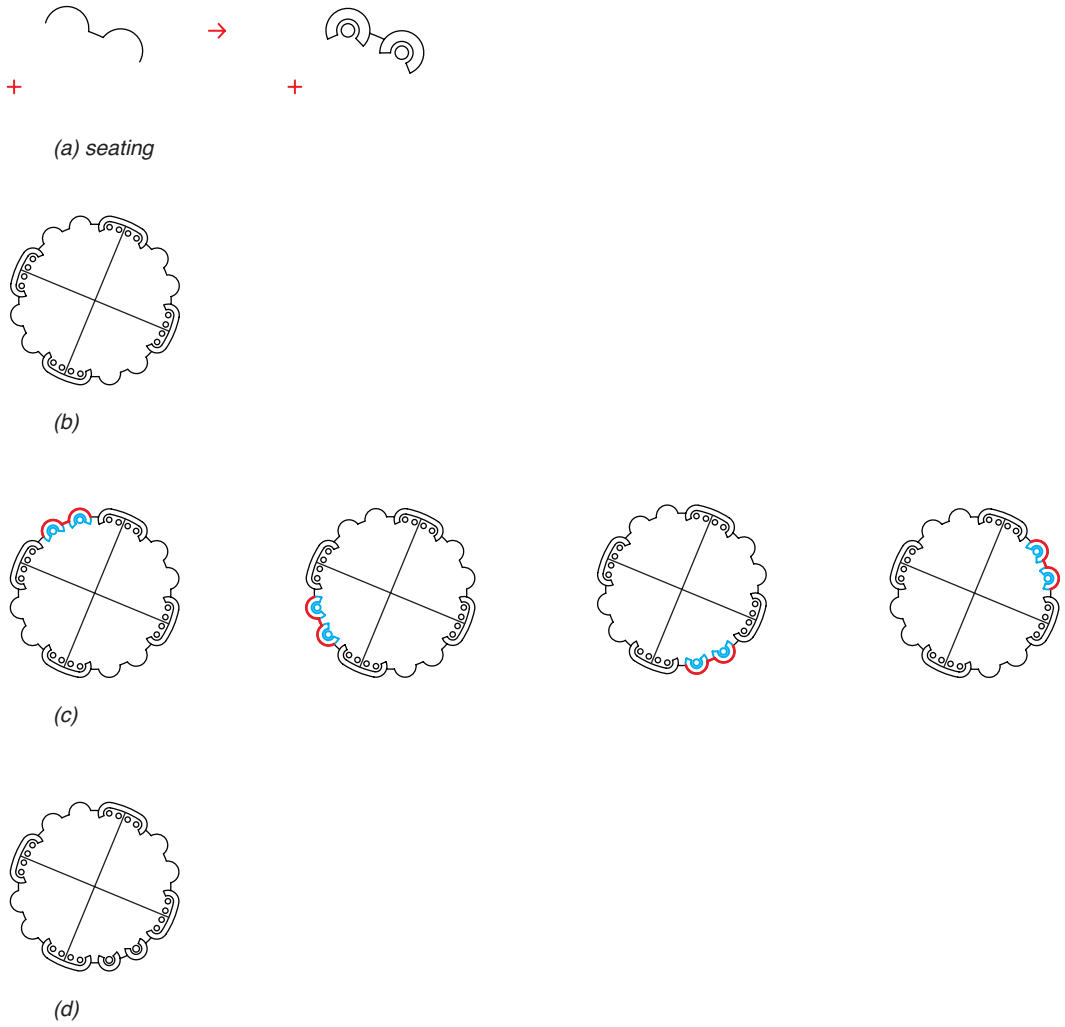
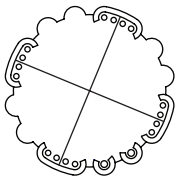


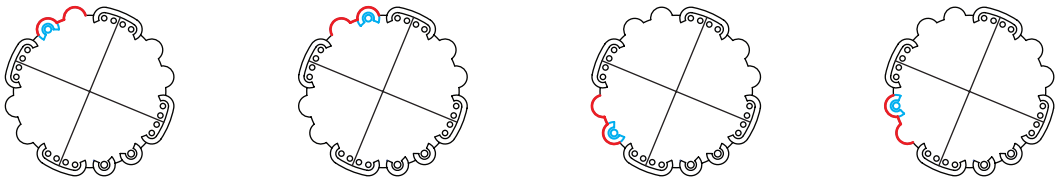
Figure 5.6 Midnight Sun grammar - reconstruction rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

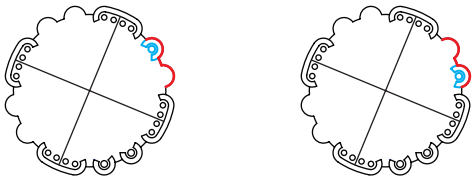
In production (Figure 5.7(b)), six matches are found in its application as shown in Figure 5.7(c). Of these six possibilities, three are applied - the second and fourth in the first row, as well as the second option in the second row - to progress the design, generating the shape given in Figure 5.7(d). These particular selections for application correspond to the rotational symmetry found in the original Midnight Sun design.

(a) seating / threshold

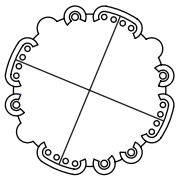


(b)





(c)



(d)

Figure 5.7 Midnight Sun grammar - reconstruction rule 3: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

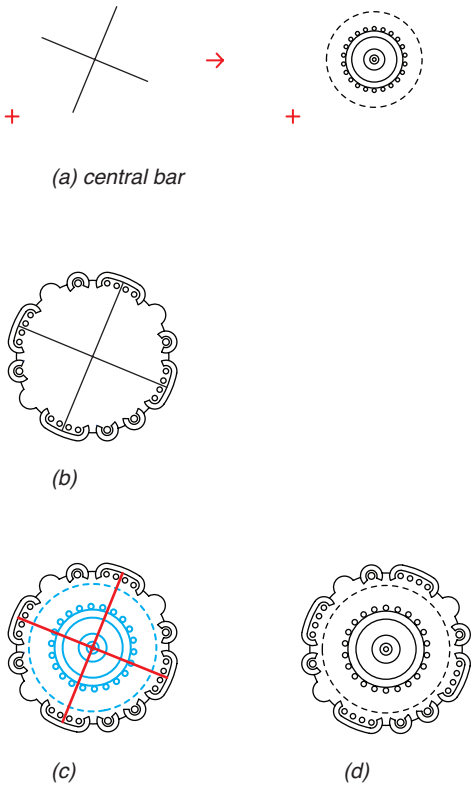


Figure 5.8 Midnight Sun grammar - reconstruction rule 4: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

The fourth and final shape rule of the reconstruction stage is shown in Figure 5.8(a). Reconstruction rule 4 is a replacement rule applied to generate the bar that reiterates the central organization of the design, and further relates to the concept of rules that offset forms in its formal operations that emphasize and repeat the circular geometry of the design. As with all the replacement rules in this stage, the schema $x \rightarrow y$ describes this rule and suggests the widespread possibilities for alternative designs in other grammars and computations. When this rule is applied to the shape depicted in Figure 5.8(b), a single match is found as previewed in Figure 5.8(c). The resulting design of Figure 5.8(d) matches the schematic design of the Midnight Sun.

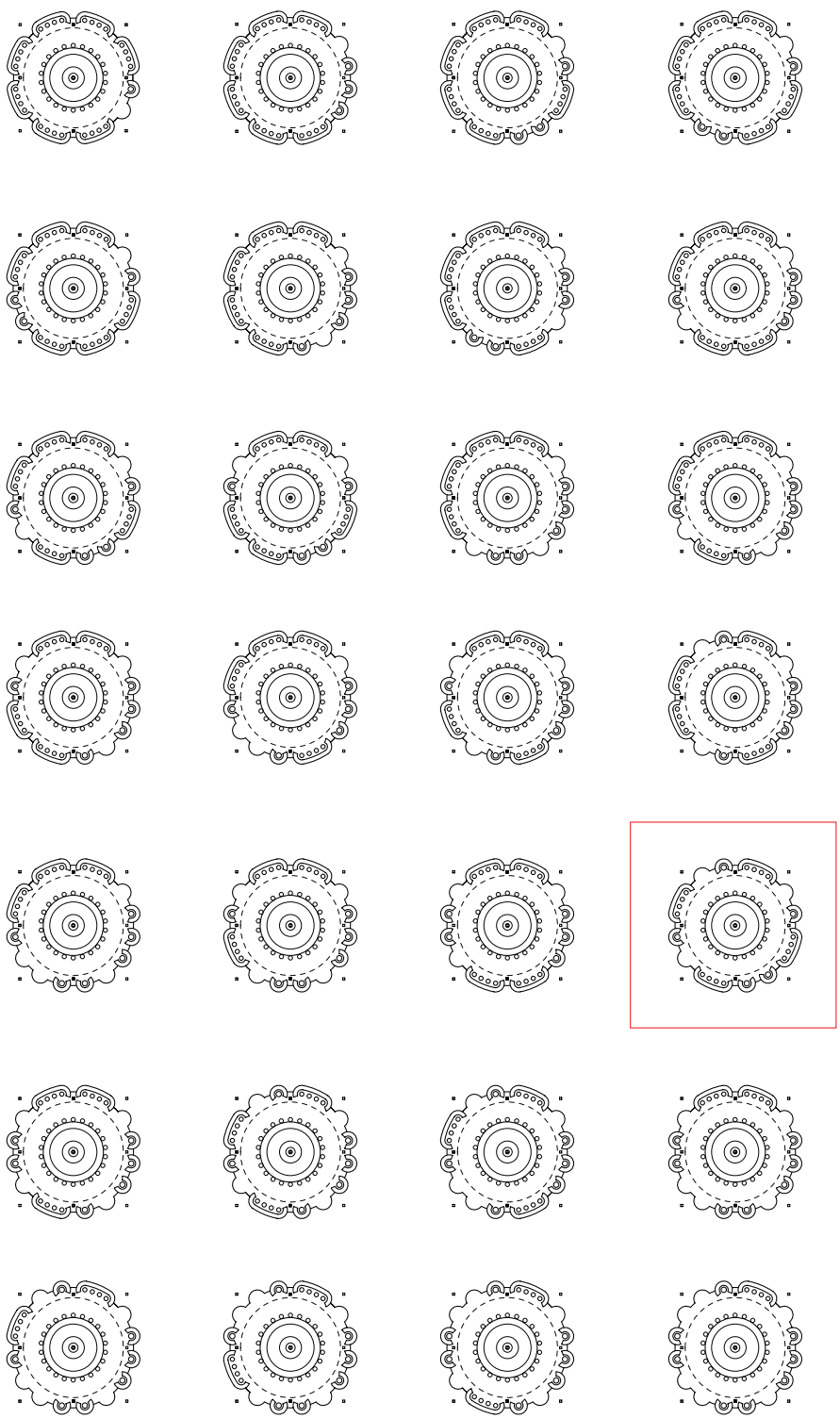


Figure 5.9 Midnight Sun variations: catalog of twenty-eight design iterations generated in *Shape Machine*.

The identity, transformation, and reconstruction stages of the Midnight Sun grammar provide a structure for interpreting how spatial relationships in Entelechy I correlate to the interior design of the cocktail bar. Once understood in the context of rule schemata and the additional rules that can be designed to follow a similar ruleset, a series of variations can be produced. A sample catalog of these designs is given in Figure 5.9 to provide a visual counterpart to this argument, with the original design of the Midnight Sun highlighted by a red square.

These iterations demonstrate possible outcomes when the transformation grammar is further adapted for other constraints to vary seating densities, circulation thresholds, and their respective configurations. Due to their rule-based translation directly from the spatial relationships of the conceptual figure defining the hollow column in Entelechy I, they also can be thought of as cross-products combining the variations of the column studied in Figure 3.18 and the original Midnight Sun design. A key feature that comes forward by looking at the catalog of Midnight Sun variations is how the designs reinterpret the undulating, articulated exterior enclosure of Entelechy I to a centrally planned, circular geometry to explore the arrangement of symmetries, asymmetries, offsets, solids, voids, various polyrhythms, and more within the constraints of a radial organization. Conceptually, these transformations can be seen as a reworking that reconsiders the rules of the Entelechy grammar and their organizational interest in self-similarity, figure-ground reversals, boundary ornamentation, and offset forms to work for the conditions, modularity, and singularity of the cocktail bar design. From this view, the design of the exploded column and the design of the bar interior can both be seen as formal organizations that are equipped for self-similar adaptation and change, a process further related to hotel design in the next section.

5.3 The Atrium Hotel Grammar

Portman's architectural corpus is recognized for works in hospitality design, especially the atria hotels that serve as the basis here for an understanding on how designs for a building relate to the organizational structure of Entelechy I. Three specific works of focus drive the study of the atria here, including: a) the 1967 Hyatt Regency in Atlanta, Georgia (Figure 3.29; Figure 3.30); b) the 1971 Hyatt Regency O'Hare in Chicago, Illinois (Figure 3.31; Figure 3.32); and c) the 1985 Marriott Marquis Times Square in New York, New York (Figure 3.33; Figure 3.34). How these designs can be interpreted in relation to the house will be demonstrated following the tripartite structure of an identity stage, a transformation stage, and a reconstruction stage as in the previous section.

The identity stage starts the process with one shape rule. A single identity rule, similar to the identity rule of the Midnight Sun grammar in its focus on the circular figure, is utilized as illustrated in Figure 5.10. This rule is applied to extract the essential conceptual figure of the hollow column in Entelechy I, the basis for transformations between the house and the atria hotels (see Figure 4.6). As before, the search and selection of this part serves as the basis for development in the transformation stage.

The transformation stage consists of six shape rules to transform the identified figure. Transformation rule 1 (Figure 5.11(a)) is a scaling rule to modify the diameter of

i. identity

Figure 5.10 Atrium Hotel grammar - Identity rule.

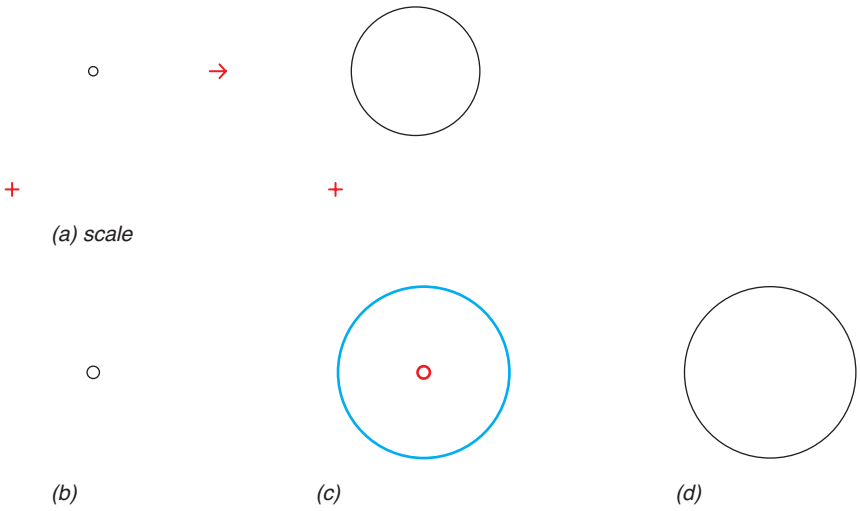


Figure 5.11 Atrium Hotel grammar - transformation rule 1: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

the original figure in the house (Figure 5.11(b)) to a new diameter for the hotel. This rule operates under the schema *x* → *t(x)*, where *t* is a scalar transformation which could be resized for any context. Here, the rule rescales the figure to address the scale of a building, as previewed in Figure 5.11(c) and applied in Figure 5.11(d). Then, transformation rule 2 is applied to replace the circular figure with an alternative Platonic geometry, specified as a rectilinear figure to correspond to the three atria studied here (Figure 5.12(a)). This rule can be described by the schema *x* → *y*, to replace any shape assignment with a new shape. When this rule is implemented on the design of Figure 5.12(b), a single match is found (Figure 5.12(c)) to substitute the circle for the square achieved when the rule is applied (Figure 5.12(d)). Next, transformation rule 3 (Figure 5.13(a)) is applied to offset the geometry of the figure outline. These two rules essentially revisit the concepts of Platonic rules, figure-ground reversal rules, and offset rules from the Entelechy grammar at the scale of the atria hotel. This rule can be alternatively understood by the schema *x* → *x + t(x)* to define a compound offset operation, *t(x)*, where the transformation describes

a copy, scaling, and translation of the *LHS* shape. When this rule is applied to the square figure (Figure 5.13(b)), a single match is found (Figure 5.13(c)) and applied to achieve the design of Figure 5.13(d).

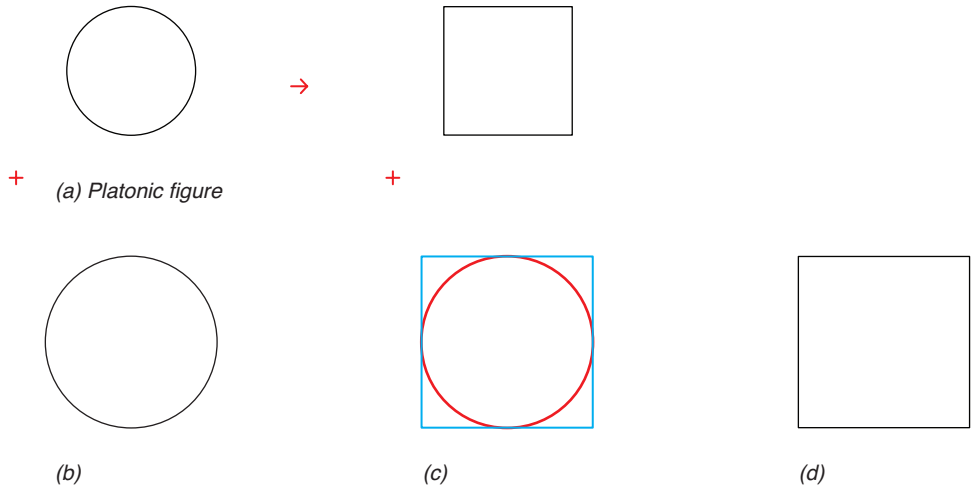


Figure 5.12 Atrium Hotel grammar - transformation rule 2: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

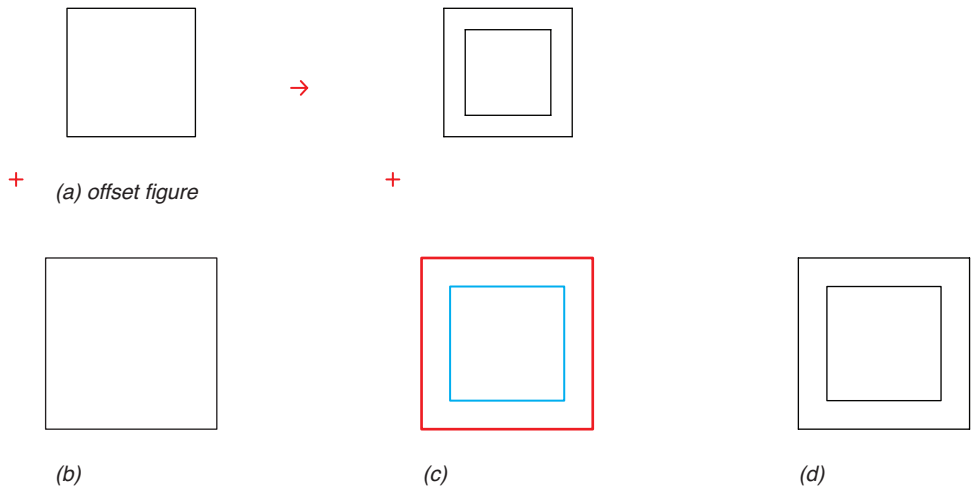
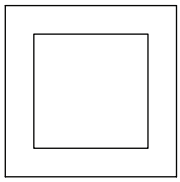


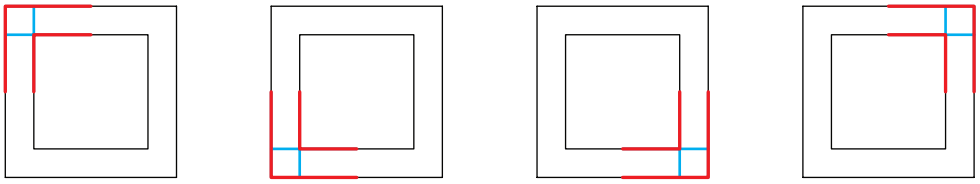
Figure 5.13 Atrium Hotel grammar - transformation rule 3: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

The last three transformation rules of this stage modify the offset figure to distinguish corner and edge conditions. Transformation rule 4 (Figure 5.14(a)) begins this process by adding a corner division to the rectilinear geometry. The visual rule can be redefined by the schema $x \rightarrow x + prt^{-1}(x)$ to emphasize the constructive relation of the corner as an inverse part, $prt^{-1}(x)$, of the *LHS* shape. When transformation rule 4 is applied

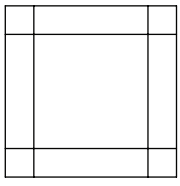
(a) add corner division



(b)



(c)



(d)

Figure 5.14 Atrium Hotel grammar - transformation rule 4: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

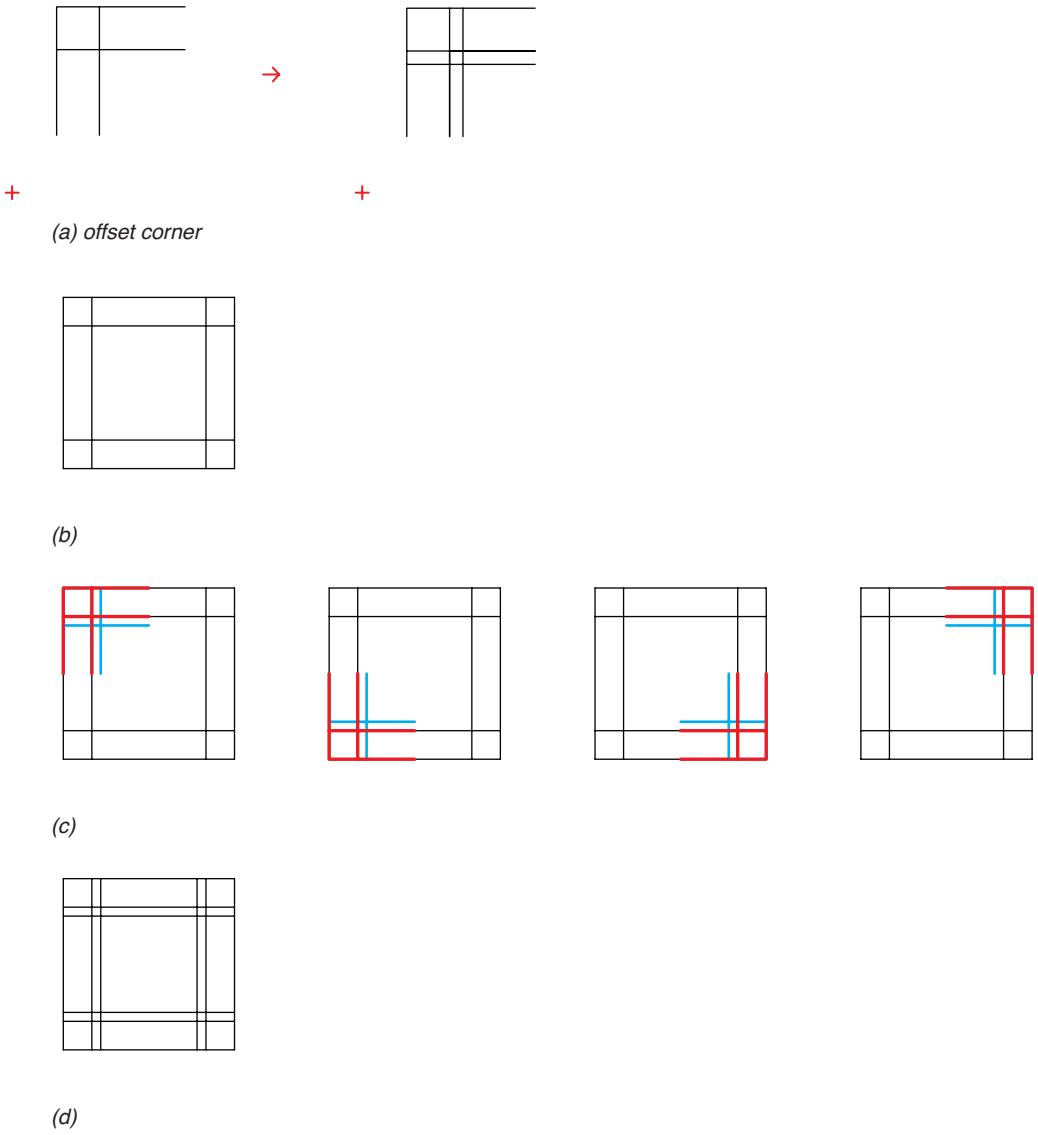
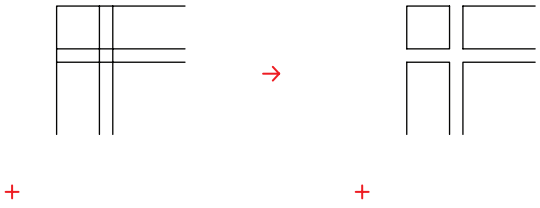


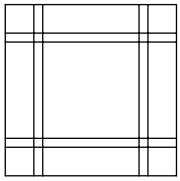
Figure 5.15 Atrium Hotel grammar - transformation rule 5: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

to the shape produced with the previous rule application (Figure 5.14(b)), four matches are found (Figure 5.14(c)) and implemented in parallel to generate the design of Figure 5.14(d). Next, transformation rule 5 (Figure 5.15(a)) is implemented. This rule correlates to the schema $x \rightarrow x + t(prt(x))$ to offset a corner subdivision. The application of this rule to the shape in Figure 5.15(b) generates four matches as previewed in Figure 5.15(c). When this rule is applied for all matches, the result is the design of Figure 5.15(d). Lastly,

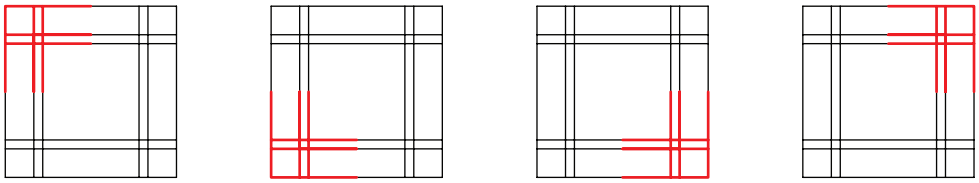
transformation rule 6 (Figure 5.16(a)), is applied to the shape given in Figure 5.16(b). This rule is related conceptually to the schema *x* → *prt(x)* to distinguish select parts of a shape. When all four matches, shown in Figure 5.16(c), are applied, the design shown in Figure 5.16(d) is produced. This shape is the basis for generating three prototypes that correlate to the three atria hotels of the corpus in the reconstruction stage.



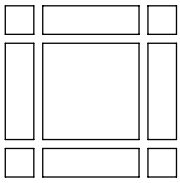
(a) define parts



(b)



(c)



(d)

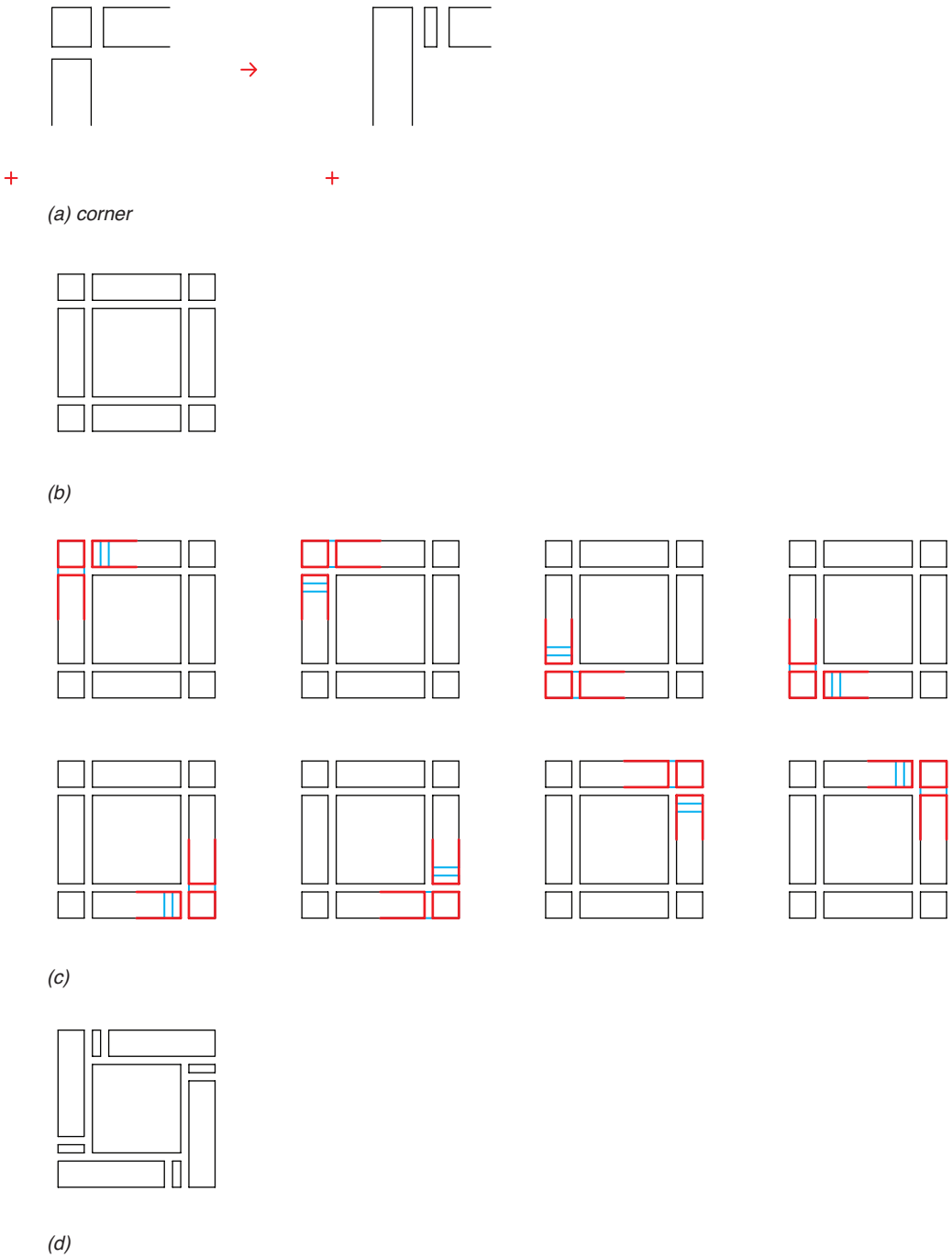
Figure 5.16 Atrium Hotel grammar - transformation rule 6: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

The reconstruction stage consists of three shape rules, each corresponding to a corner detail that redefines the relationships between corner and edge in the underlying double-bounded square design generated in the previous stage. All three rules consist of the same *LHS* shape to specify the replacement of this part with a new spatial relationship, and each *RHS* shape maps to one of the three hotels from Portman's existing corpus. In effect, these rules all reconsider the concept of boundary ornamentation as a function of the corner definition in the atria hotel designs. These rules can be unified by the general replacement schema, $x \rightarrow y$, although more complex schemata are needed to capture the specificity of each rule.

For example, reconstruction rule 1 (Figure 5.17(a)) extends one edge to absorb the corner. The second edge pulls back in response and an offset corner element shifts to transition between the two edges with a double reveal. The application of this rule to the shape in Figure 5.17(b) generates two matches for every corner so that eight applications are possible as previewed in Figure 5.17(c). When the rule is implemented with the four matches that correspond to the rotational symmetry of the 1967 Hyatt Regency Atlanta (Figure 3.29), the conceptual atrium design of Figure 5.17(d) is achieved.

Reconstruction rule 2 (Figure 5.18(a)) maintains both edges of the *LHS* and replaces this shape with an alternative that reiterates the specification of Platonic geometries in a rule that exchanges of square for circle. The application of this rule to the shape in Figure 5.18(b) generates a single match for every corner so that four applications are possible as previewed in Figure 5.18(c). When the rule is implemented for all matches in parallel, a conceptual design that matches the organization of the 1971 Hyatt Regency O'Hare (Figure 3.31) is achieved as given in Figure 5.18(d).

Lastly, reconstruction rule 3 (Figure 5.19(a)) extends one edge to absorb the corner, while the second edge stays in its original position. The application of this rule to



(a) corner

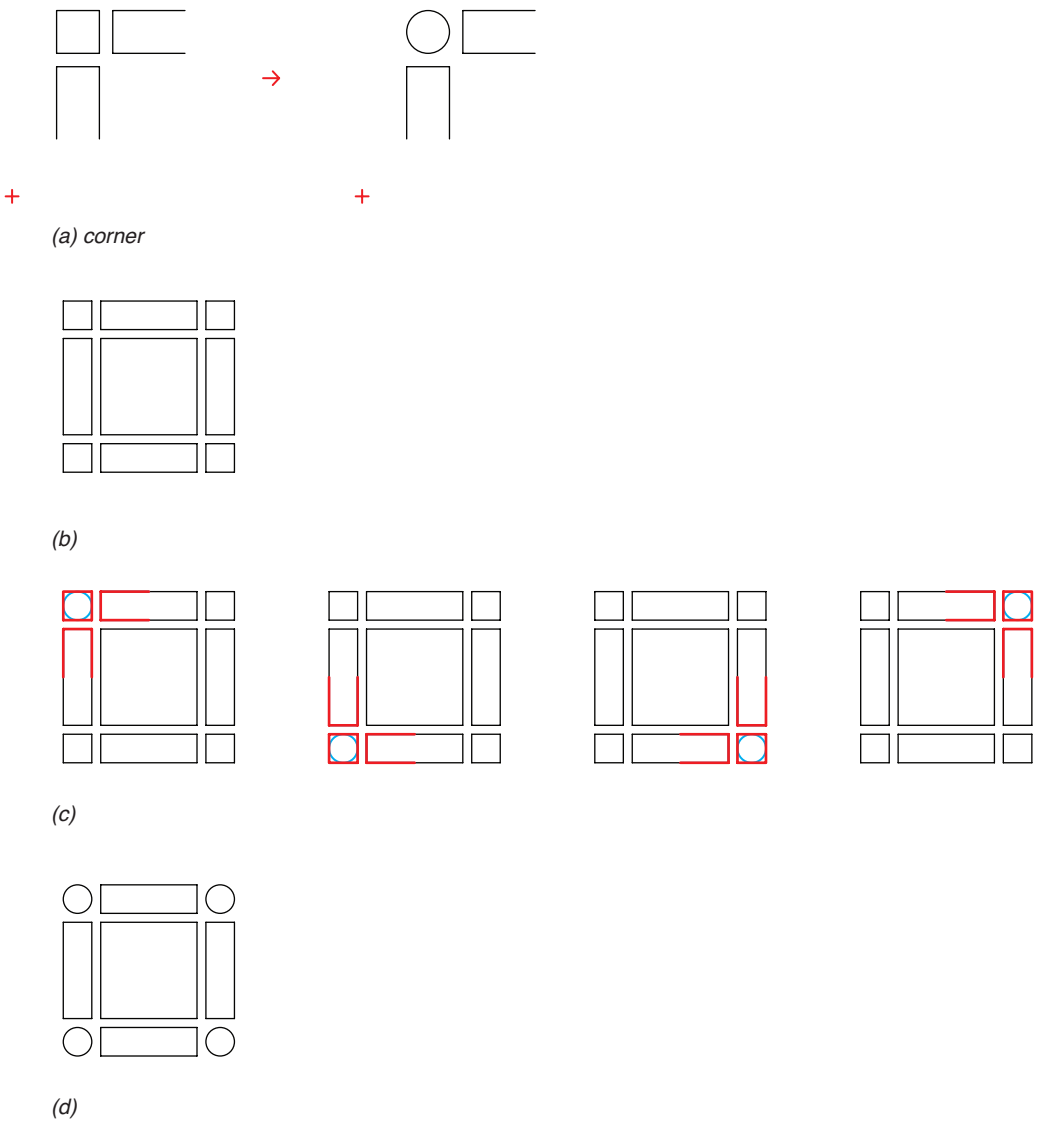
(b)

(c)

(d)

Figure 5.17 Atrium Hotel grammar - reconstruction rule 1: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

the shape given in Figure 5.19(b) results in a pair of matches for every corner, as shown in Figure 5.19(c). When the rule is implemented with the four matches that correspond to the bilateral symmetry of the 1985 Marriott Marquis Times Square (Figure 3.33), the design of Figure 5.19(d) is produced.



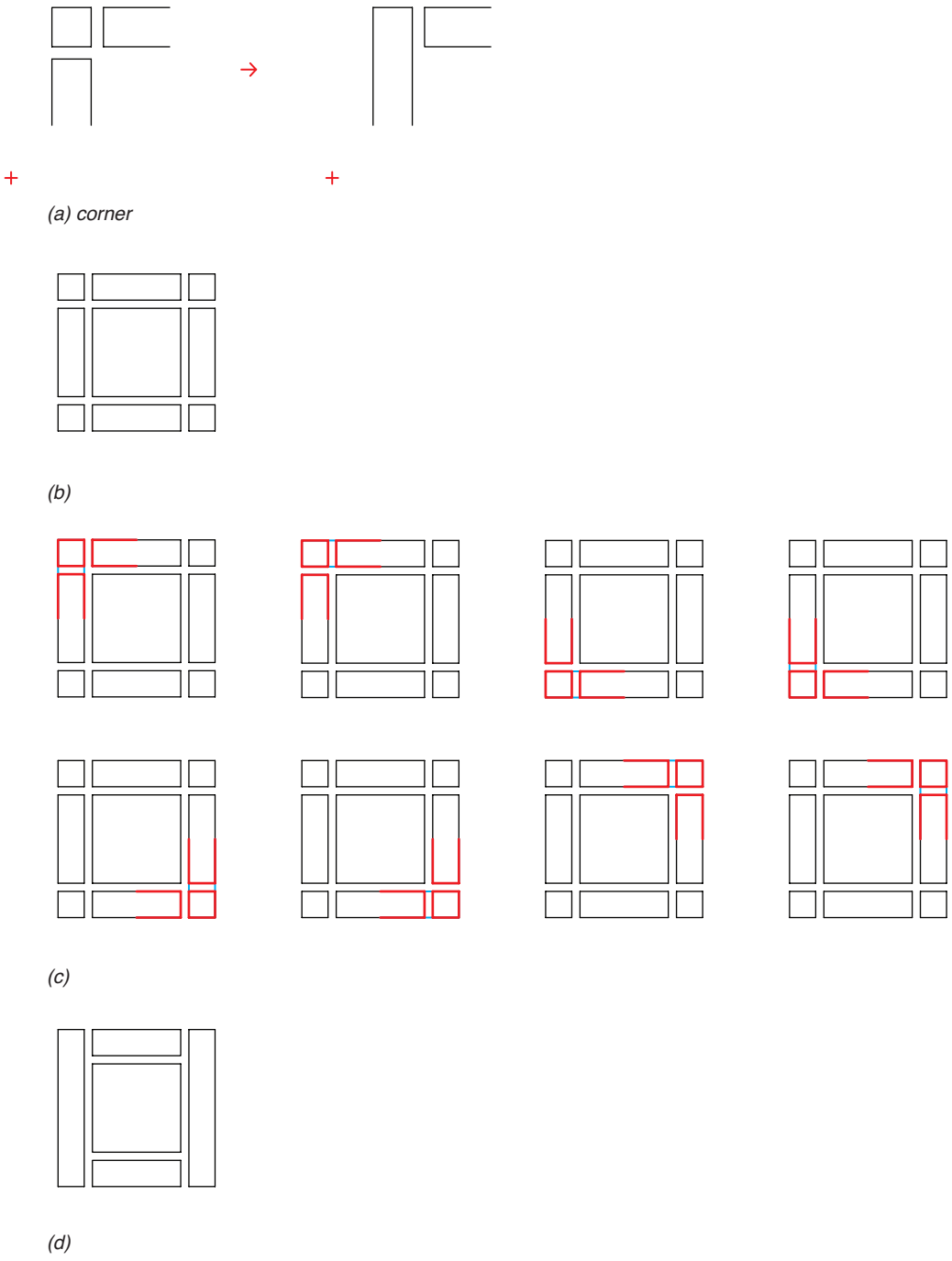
(a) corner

(b)

(c)

(d)

Figure 5.18 Atrium Hotel grammar - reconstruction rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.



(a) corner

(b)

(c)

(d)

Figure 5.19 Atrium Hotel grammar - reconstruction rule 3: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

The identity, transformation, and reconstruction stages of the Atrium Hotel grammar provide a structure for interpreting how spatial relationships in Entelechy I correlate to the hospitality design of three atria hotels: the Hyatt Regency Atlanta, the Hyatt Regency O'Hare, and the Marriott Marquis Times Square. Considering the design possibilities of this structure with additional rules that address the details and modular requirements of typical hotel operators (see Ligler and Economou, 2019a), a series of variations can be produced. A sample of these designs is given in Figure 5.20 to provide a visual counterpart to this argument. These iterations are organized in columns (1- 4) and rows (a – f) to study how the three corner rules apply to varying modular hotel structures. Columns 1, 2, and 3 correspond directly to corner rules 1, 2, and 3 (Figure 5.17, Figure 5.18, Figure 5.19). Column 4 includes designs that combine corner rules to offer hybrid iterations. Rows a-f offer variations with increasing guestroom capacity from top to bottom. Together, the variations suggest how the transformation grammar could be adapted to automate hotel designs.

Even more, the spatial relationships defined by the figural columns in Entelechy I are conceptually established to a selection of the atrium hotels. The process, especially in the transformation stage, demonstrates the usefulness of rule schemata in formalizing design actions that allow for a range of shape substitutions. This suggests how rules for other shape assignments, like a triangular site, can be further customized to produce hospitality designs. In all of the designs, Platonic rules, boundary ornamentation rules, and offset rules are particularly exhibited to establish further connection to the design of Entelechy I. In addition, the variations bring forward other relations, for example, how column 2 begins to articulate the arrangement of a group of buildings, suggesting the move towards urban design in the next section.

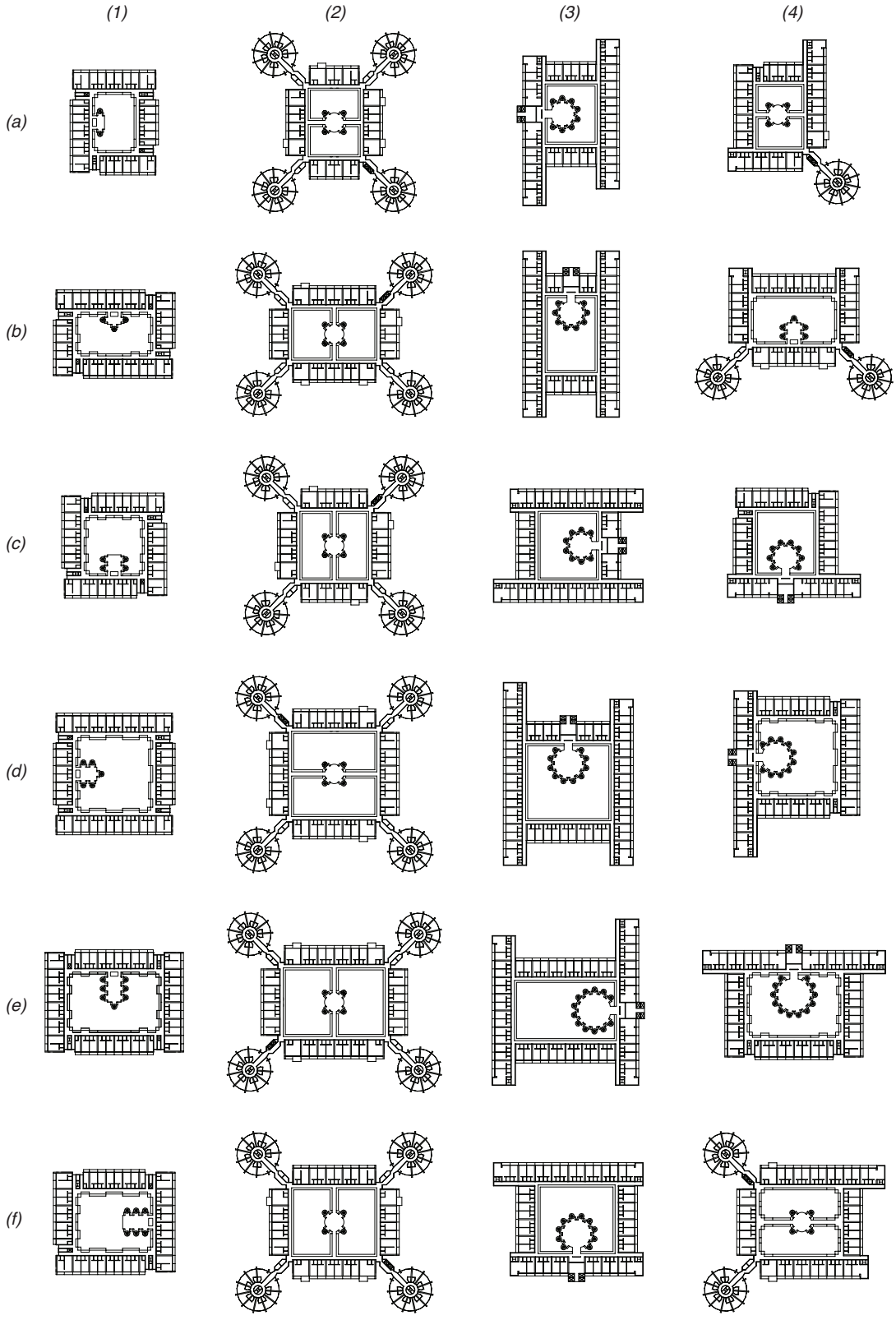


Figure 5.20 Atrium Hotel variations: Twenty-four automated plans to describe hotel design variations produced in *Shape Machine*.

5.4 The Renaissance Center Grammar

Portman's urban ideals are rooted in the concept of the coordinate unit, a module he described in relation to the Renaissance Center (Figure 3.39; Figure 3.40) in *The Architect as Developer* (Portman and Barnett, 1976). Here, this project serves as the basis for an understanding on how urban designs for a group of buildings relate to the organizational structure of Entelechy I. These relations are proposed in the Renaissance Center grammar, which includes an identity stage, a transformation stage, and a reconstruction stage as in the two previous sections. However, the starting point is different. The initial identity rule (Figure 5.21) is derived from the configurational state of the Entelechy grammar when the major grid module is developed to include the figural minor spaces at four corners (Figure 4.6). This structure, which can be thought of as a concept sketch or parti for the domestic coordinate unit, is the basis for transformations between the house and the Renaissance Center at three different scales. The search and selection of this part, described as an identity rule by the schema $x \rightarrow x$, is applied to start the production and move into the transformation stage.

The transformation stage consists of four rules to address the translation from the conceptual coordinate unit to three scales of development at the Renaissance Center. These scales relate to the different compositions of buildings in the design, including: a) the high-rise group scale *A*; b) the high-rise tower scale *B*, and c) the mid-rise group scale

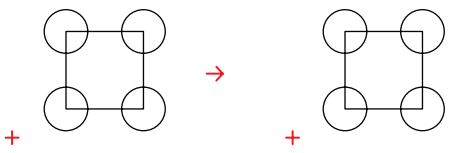


Figure 5.21 Renaissance Center grammar - Identity rule.

C. Each scale is first developed with a pair of transformation rules that follow the same schema, representing rules that multiply spaces and that redefine figures. The first is a scaling rule, described by the schema $x \rightarrow t(x)$ to resize the domestic coordinate unit from the scale of a house to an urban scale, and the second is a figure rule, described by the schema $x \rightarrow y$ to replace various geometries within the same schematic arrangement.

Transformation rule 1 defines a scalar transformation from the scale of the house to an urban context. This rule, shown in Figure 5.22(a), results in a single match when applied to the shape given in Figure 5.22(b). A preview of the scalar transformation described in the rule is depicted in Figure 5.22(c) and results in the scaled shape of Figure 5.22(d). Variations on this rule are used for scales *A*, *B*, and *C* to resize the arrangement for each context. Next, transformation rule 2 (Figure 5.23(a)) is the corresponding figure

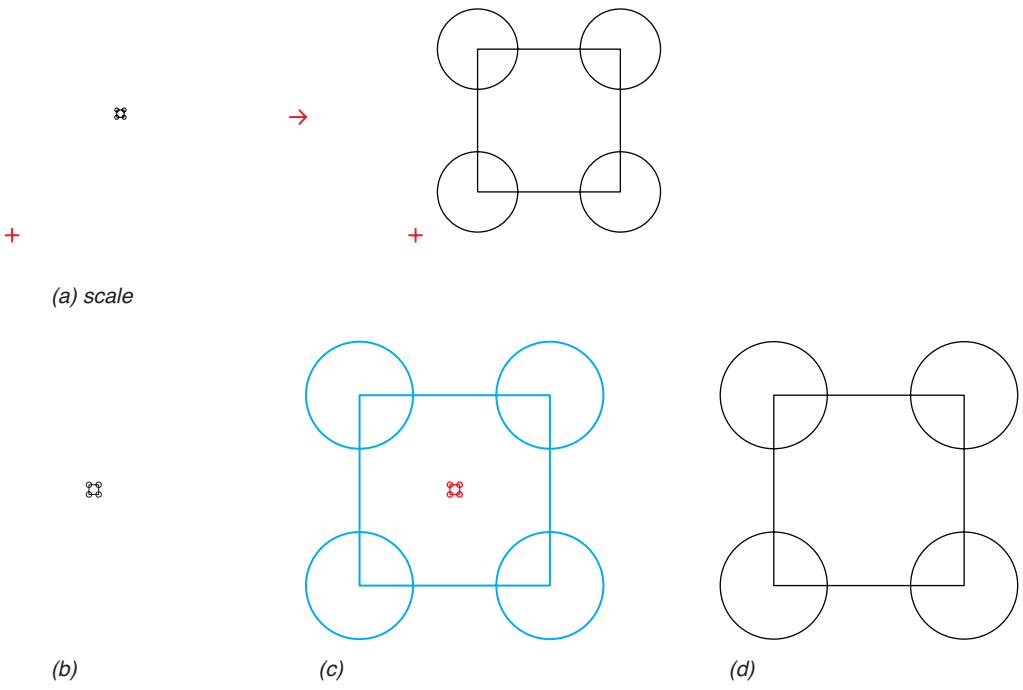


Figure 5.22 Renaissance Center grammar - transformation rule 1: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

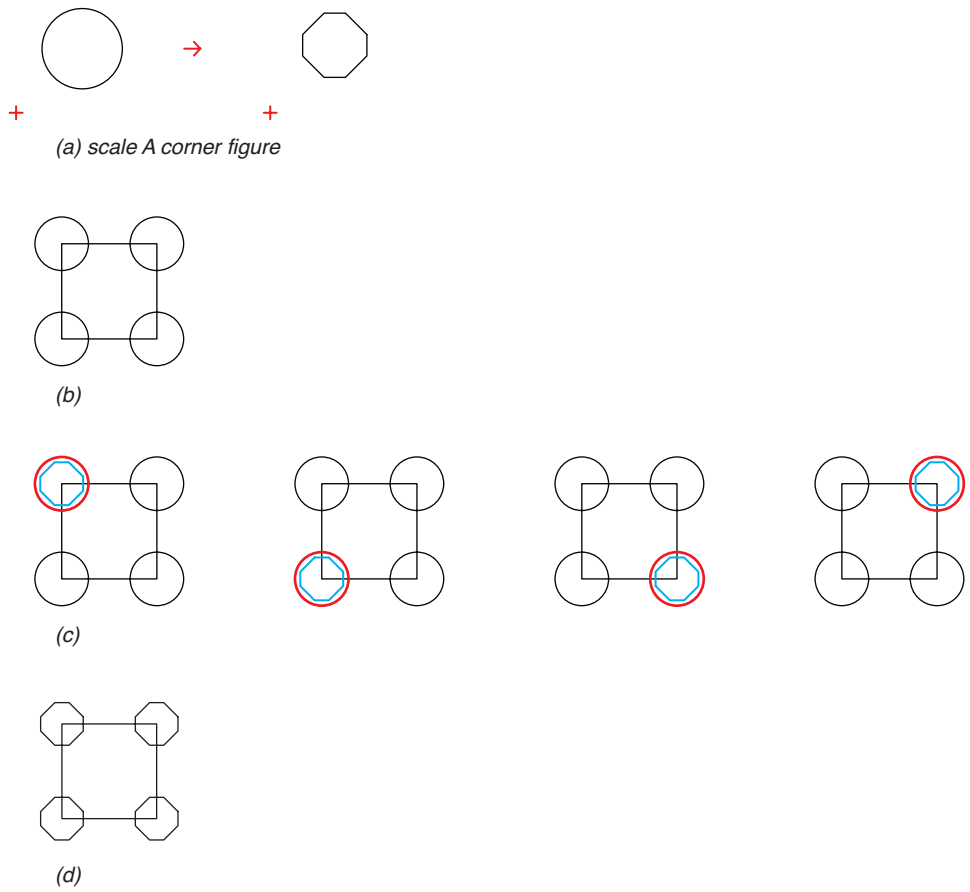


Figure 5.23 Renaissance Center grammar - transformation rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

rule proportioned for scale *A.* This rule replaces the circular figures at the corners of the design in Figure 5.23(b) with an alternative Platonic figure. The application of this rule produces four matches as shown in Figure 5.23(c). When all four matches are applied, the design of Figure 5.23(d) is produced with characteristic octagonal corners. This shape is the transformed basis for the high-rise tower group in the Renaissance Center design.

Transformation rule 3 (Figure 5.24(a)) transitions to scale *B* to translate from the house to a single high-rise tower. This scale is visually described in the shape given in Figure 5.24(b), the initial shape for the replacement of the corner figure at this scale.

Transformation rule 3 describes this exchange, which reworks the circular corner figure and the part of the square within its diameter as a new shape as described in the rule. When this rule is applied, four matches are found, one for each corner, as previewed in Figure 5.24(c). After the application of all matches, the design of Figure 5.24(d) is achieved, depicting a transformation at the scale of the individual high-rise towers.

To complete the transformation stage, transformation rule 4 (Figure 5.25(a)) addresses scale *C* to transition to a group of mid-rise towers. This scale is visually described in the shape given in Figure 5.25(b) the initial shape for the replacement of the corner figure as a Platonic substitution at this scale. Transformation rule 4 is similar to

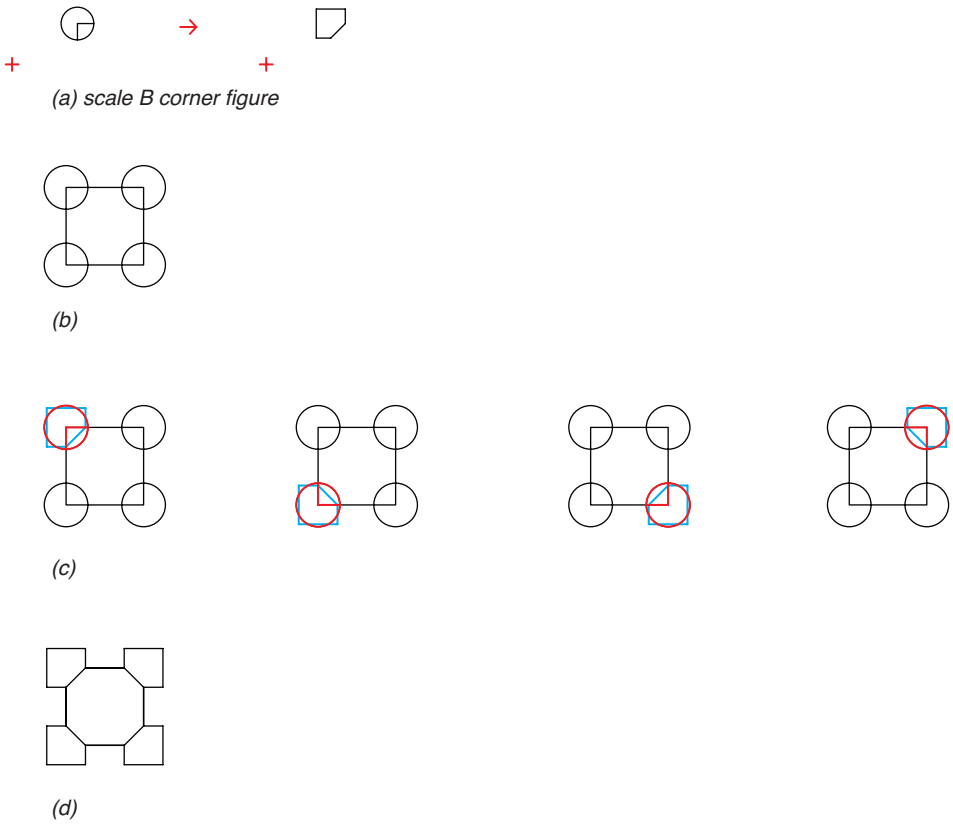


Figure 5.24 Renaissance Center grammar - transformation rule 3: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

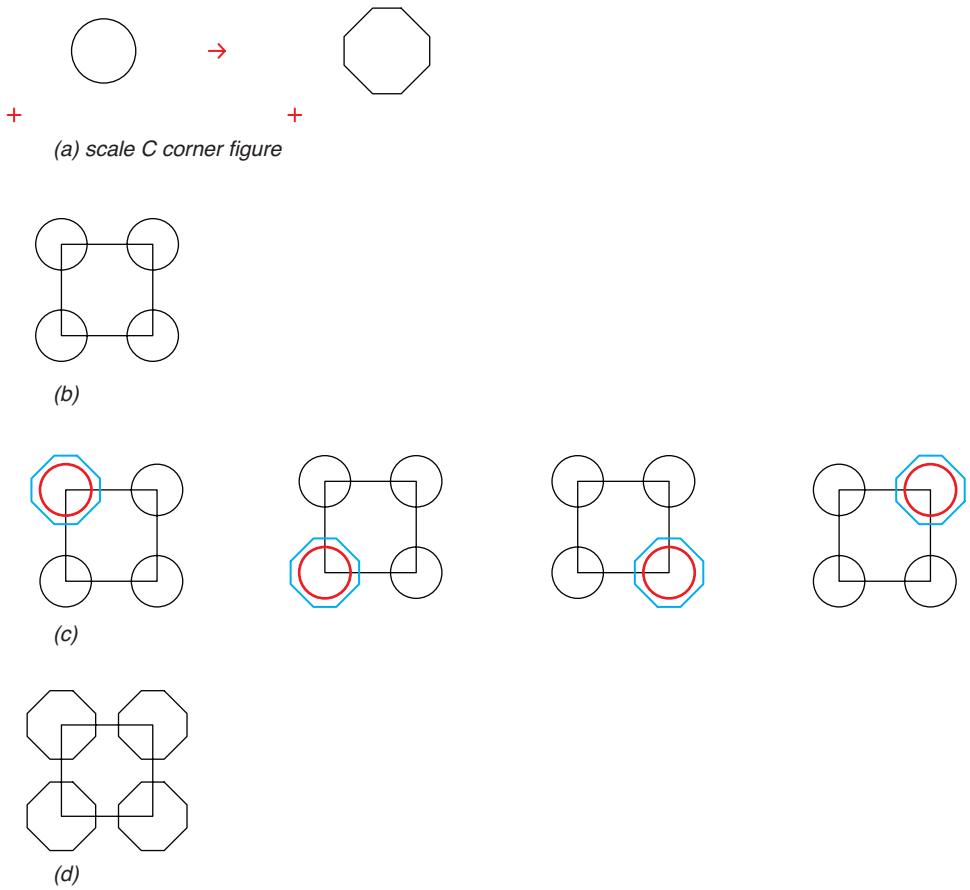


Figure 5.25 Renaissance Center grammar - transformation rule 4: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

transformation rule 2 (Figure 5.23) in how it replaces a circular figure with an octagonal one but note the difference in scale which corresponds to the proportional difference between the mid-rise and high-rise tower groups. When transformation rule 4 is applied, four matches are previewed as depicted in Figure 5.25(c). All four matches are applied in parallel to achieve the design shown in Figure 5.25(d), which provides the base composition for the mid-rise tower group at Renaissance Center and completes the transformation stage.

In the reconstruction stage, all three scales are addressed to produce designs that match the tower groups at the Renaissance Center. Four rules are used to generate the high-rise and mid-rise tower groups from the transformed shapes of scale *A*, *B*, and *C*. Reconstruction rules 1 and 2 focus on the high-rise tower group, which combines scales *A* and *B*. Rule 1 (Figure 5.26(a)) generates the circular tower within the central square of the scale *A* composition, an action described by the schema $x \rightarrow x + y$ to introduce a new element on the *RHS* of the rule. When this rule is applied to the shape given in Figure 5.26(b), one match is possible as previewed in Figure 5.26(c). The application of the rule produces the design of Figure 5.26(d).

Reconstruction rule 2 (Figure 5.27(a)) combines scales *A* and *B* to locate the individual high-rise towers as corner figures of the tower group, an action alternatively described by the schema $x \rightarrow prt(x) + y$. The schema captures nicely how part of shape on the *LHS* of the rule, *prt(x),* is common to both scales *A* and *B*. This part is the shared octagonal figure, while the *RHS* of the rule completes the tower shape with the addition of four corner elements, described by the shape *y* in the schema, to define the podium composition. When applied to the high-rise tower group design illustrated in Figure 5.27(b), the application of rule 2 results in four matches (Figure 5.27(c)) corresponding to each of the four corners of the larger arrangement. All four matches are applied to achieve the definition of the high-rise tower group of the Renaissance Center (Figure 5.27(d)), a grouping that emphasizes formal recursions in Portman's work, with the same organization driving the group of buildings and the individual buildings too.

To complete the reconstruction stage, rules 3 and 4 focus on the mid-rise tower group, which correlates to scale *C*. Rule 3 (Figure 5.28(a)) rotates the central square defining the mid-rise tower organization generated in the previous stage (Figure 5.28(b)).

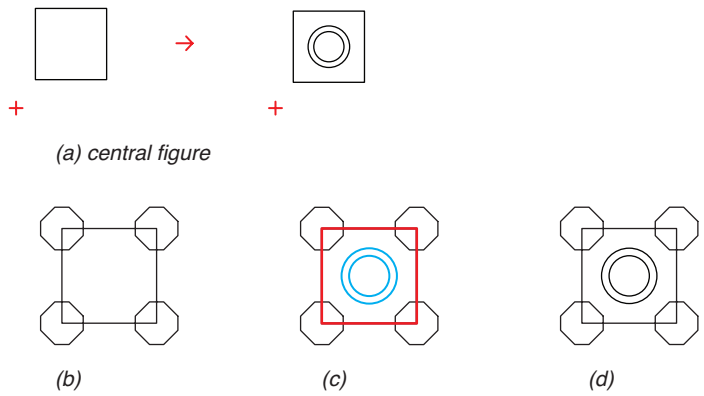


Figure 5.26 Renaissance Center grammar - reconstruction rule 1: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

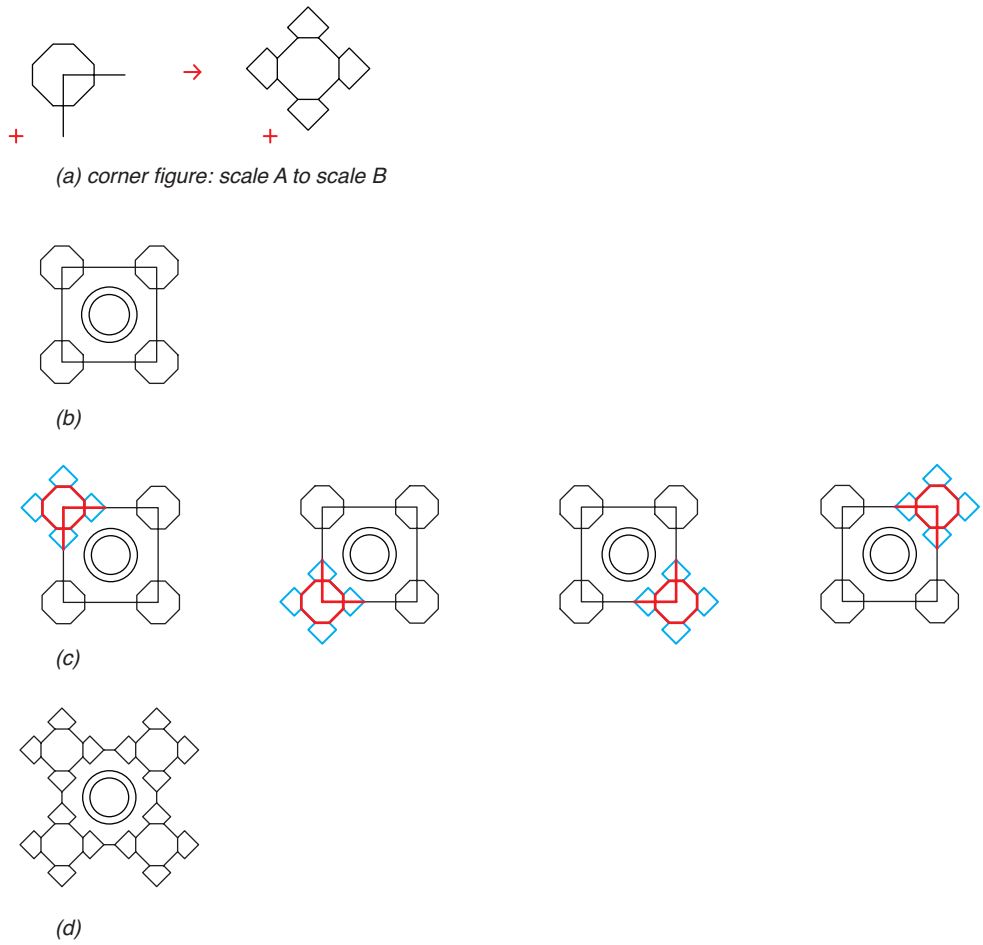


Figure 5.27 Renaissance Center grammar - reconstruction rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

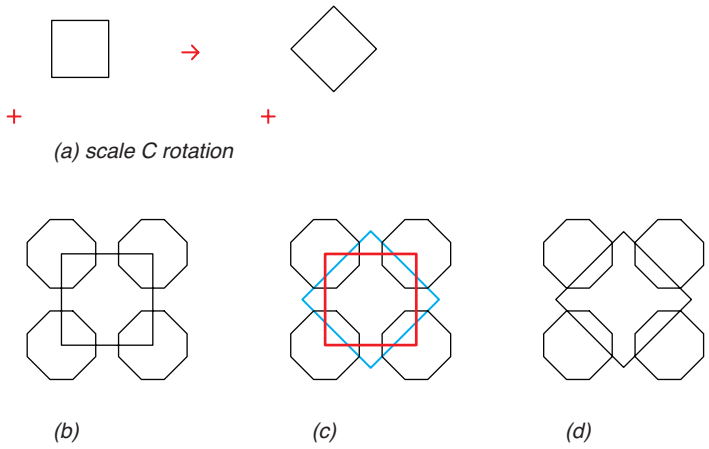


Figure 5.28 Renaissance Center grammar - reconstruction rule 3: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

The application of rule 3, as previewed in Figure 5.28(c), can also be specified with the schema $x \rightarrow t(x)$, where t is a rotational transformation. The resulting shape when rule 3 is applied is given in Figure 5.28(d). Rule 4 (Figure 5.29(a)) then develops this shape to match the design of the mid-rise tower group at Renaissance Center by replacing the central corner figures of the group (Figure 5.29(b)), following the schema $x \rightarrow y$. The application of this rule results in four matches as previewed in given in Figure 5.29(c). When the four applications are all implemented, the design of the mid-rise group at Renaissance Center is generated, as shown in Figure 5.28(d).

The identity, transformation, and reconstruction stages of the transformation grammar provide a structure for interpreting how spatial relationships in the organization of Entelechy I can relate to designs for a group of buildings, specifically the high-rise and mid-rise tower groups at the Detroit Renaissance Center. The adaptation of three scales in these rule sets verify relationships that can be further studied with additional rulesets to test possibilities for various tower groupings calibrated to a dense, urban context. A sample of possible urban variations is given in Figure 5.30 to illustrate this claim. These

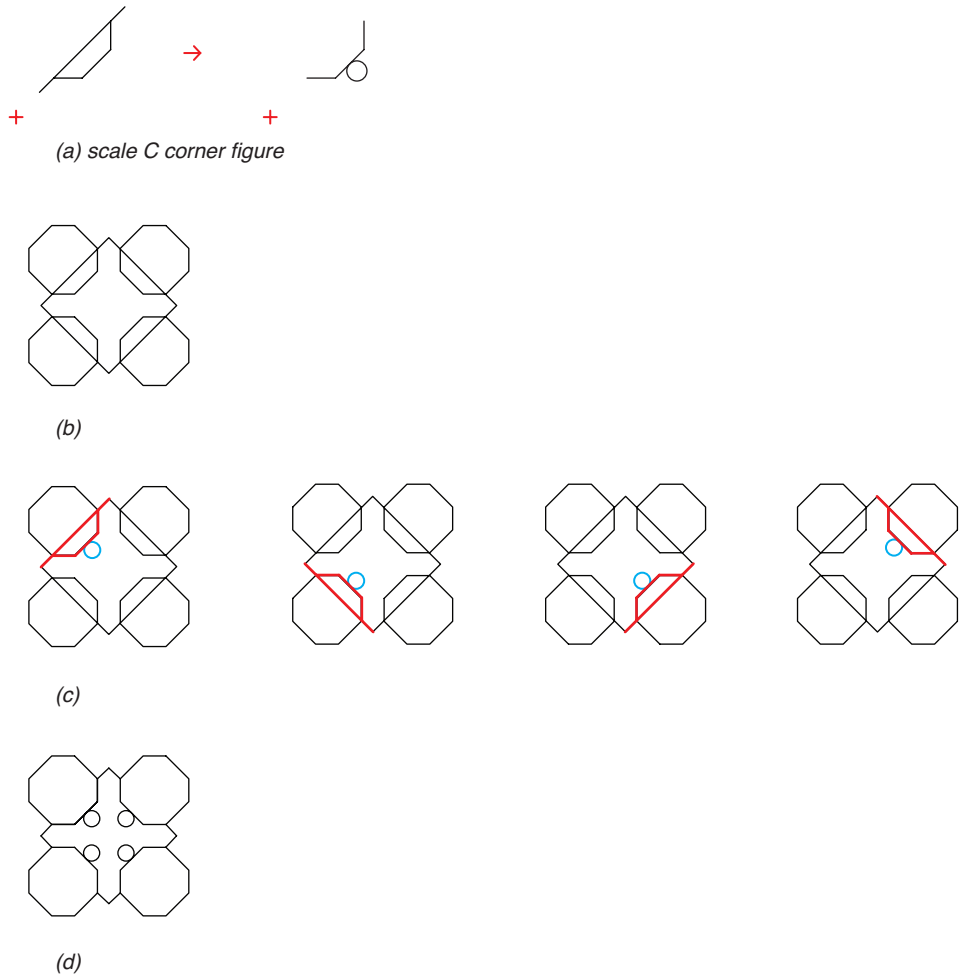


Figure 5.29 Renaissance Center grammar - reconstruction rule 4: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

thirty-two tower arrangements range from single towers to groupings of up to eight towers in both high-rise and mid-rise configurations.

These variations culminate the three transformation grammars that aim to address how designs for a room, or a restaurant, a building, or a group of buildings can be built on the structure of Entelechy through a rule-based interpretation. The urban designs nicely reiterate the coordinate unit as a basis for repetition that addresses multiple scales with a fractal-like quality. Here, this is achieved with self-similarty rules, figure-ground reversal

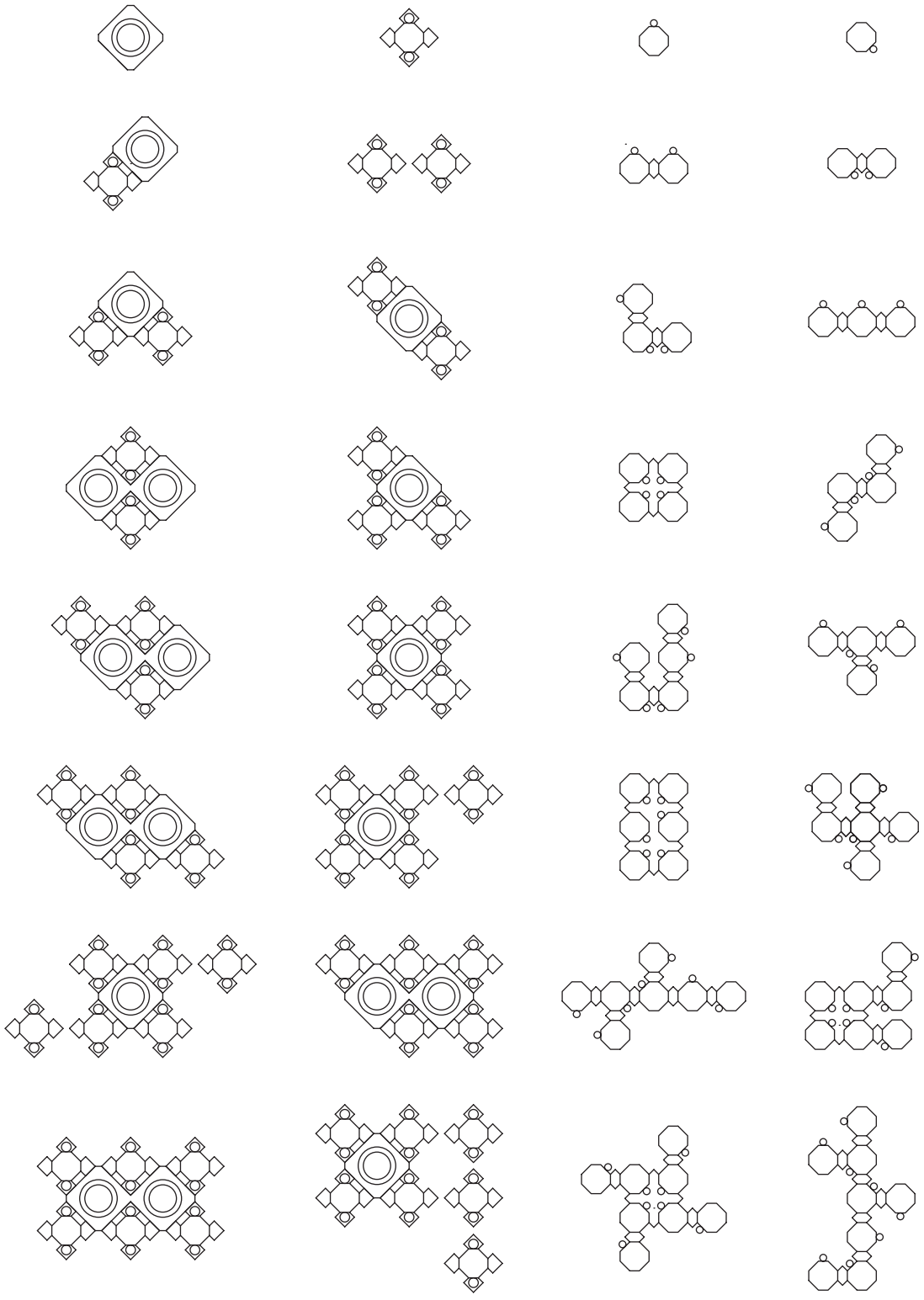


Figure 5.30 Renaissance Center variations: Catalog of thirty-two tower arrangement variations generated in *Shape Machine*.

rules, and in their combination, essentially articulate ornamental boundaries at the urban scale. In the case of the designs for a building or a group of buildings, shifting the scale of investigation - for example, to the interior podia of the Renaissance Center - would only multiply these observations. The focus on the parti in these visual arguments has aimed to avoid this complexity in exchange for conceptual clarity on the coordinate unit – and the commitment to exploring it that can be found in Portman's forms.

Particularly in the Renaissance Center variations, the compositional logic of the domestic coordinate unit from Entelechy I is replicated and mutated, demonstrating the repetition of this organization from groups of spaces in the house to groups of forms in the city. In both cases, the ability to expand and grow is embedded in the arrangement as combinations are easily linked at the corner figures. The understanding of the unity and variety possible with this same base structure brings us full circle back to residential design, where the exaggeration of the domestic coordinate unit is explored in Entelechy II, the subject of the next section.

5.5 The Entelechy II Grammar

A theory on variations in Portman's architectural language related to Entelechy I would be incomplete without the inclusion of the second house Portman built for his family, Entelechy II (Figure 3.44; Figure 3.45). Here, the two homes are interpreted following the same structure established in previous sections, with an identity stage, a transformation stage, and a reconstruction stage to interpret how residential organization evolved from one house to the next.

The starting point for this interpretation is an identity stage comprised of one shape rule. The initial identity rule (Figure 5.31) is the same shape rule used in the Renaissance

Center grammar to specify a conceptual parti of the domestic coordinate unit. The search and selection of this part, captured by the identity schema $x \rightarrow x$, is applied to start the generation process and initiate the transformation stage.

The three rules of the transformation stage develop the structure of the domestic coordinate unit in Entelechy I to accommodate the pavilion concept for Entelechy II, which is motivated by its beachfront site. Transformation rule 1 (Figure 5.32(a)) generates a dashed, rectilinear outline in relation to the square of the initial shape from the Entelechy grammar (Figure 5.32(b)). This action can be described by the schema $x \rightarrow x + y$, where

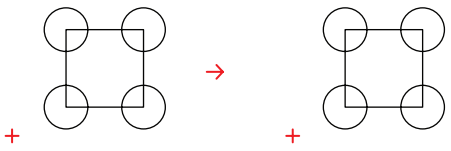


Figure 5.31 Entelechy II grammar: Identity rule.

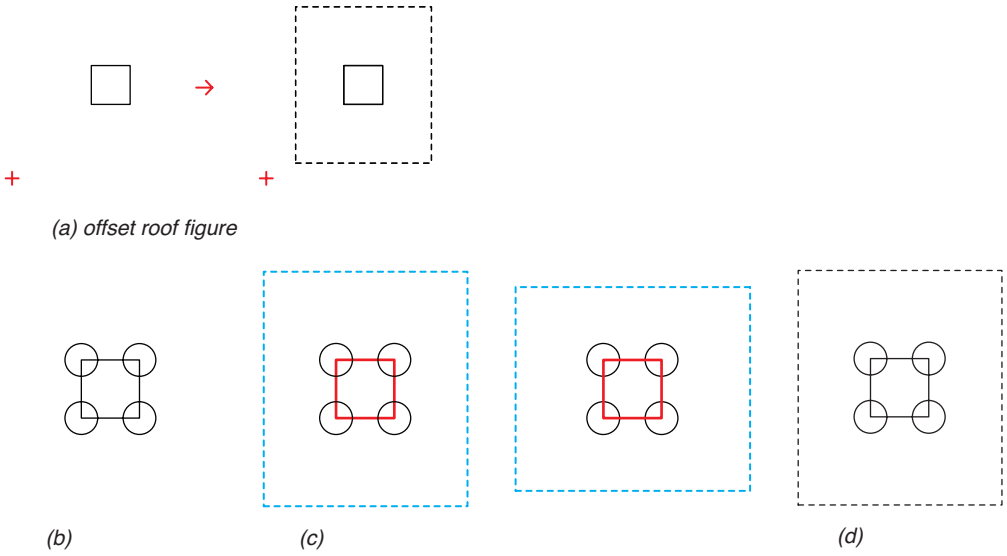


Figure 5.32 Entelechy II grammar - transformation rule 1: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

the dashed outline corresponds to the platform roof structure dominating the composition of Entelechy II. Alternatively, the rule can be defined as an offset described by the schema $x \rightarrow x + t(x)$ to covey the overhang of the roof figure above – a description that relates the rule as one that specifies offset forms. The application of this rule produces two results as previewed in Figure 5.32(c), relating to a pair of possible orientations. The selection and implementation of the first match produces the design of Figure 5.32(d).

Following this specification, transformation rule 2 (Figure 5.33(a)) decouples the square module of the domestic coordinate unit from the corner figures, an action that perhaps can be characterized by the concept of figure-ground reversal to capture the this spatial relation. The action of this shape rule can be described by the schema $x \rightarrow x + t(prt(x))$ to specify the translation of the major space (Figure 5.33(b) to align with the center of one of the shorter edges of the roofline. The rule essentially separates the major space

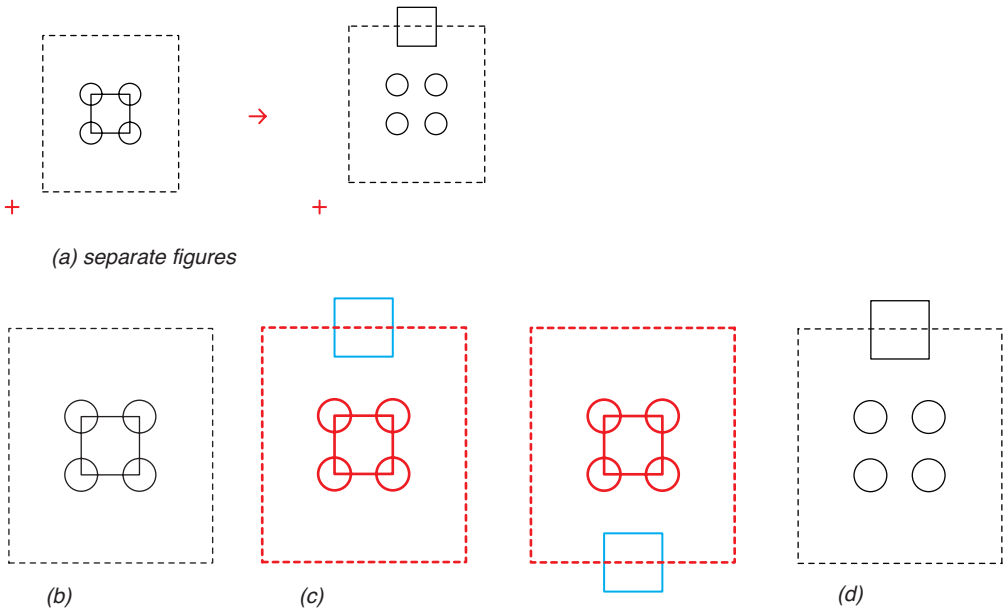


Figure 5.33 Entelechy II grammar - transformation rule 2: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

from the minor spaces and results in two possible matches as given in Figure 5.33(c). The first match is applied to produce the design of Figure 5.33(d).

It is worth pausing here to note that so far, the transformation rules for the Entelechy II grammar have not included any scaling unlike the other works considered in the corpus discussed in this chapter. This is because the domestic coordinate unit of Entelechy II comprises the same grid width and figure diameter as Entelechy I. However, the grid modules of Entelechy II are elongated rectangles oriented towards the beach in contrast to the equitable squares of the first house, a distinction taken into account in the third and final transformation rule. Transformation rule 3 (Figure 5.34(a)) describes this elongation of space, which remains centered on the edge of the rectilinear outline. Alternatively, the rule can be described by the schema $x \rightarrow x + t(prt(x))$, where the transformation stretches the two sides of the space beneath the outline of the canopy.

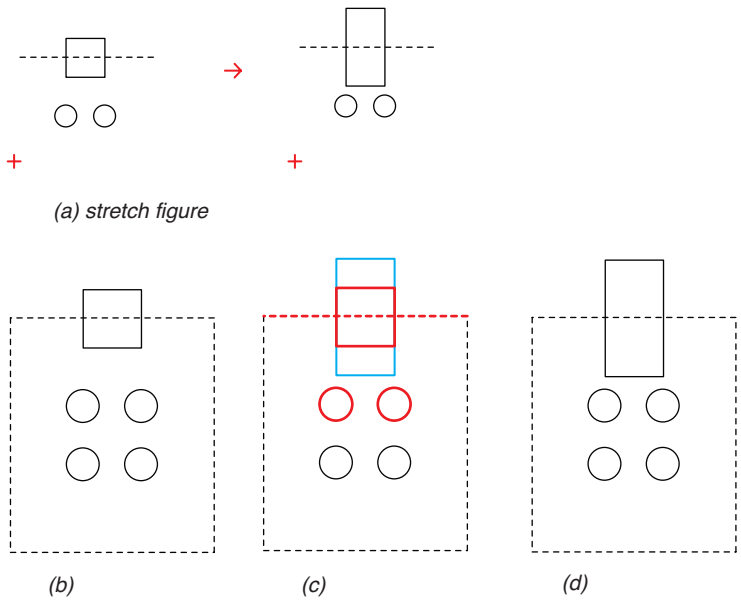


Figure 5.34 Entelechy II grammar - transformation rule 3: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

When this rule is applied to the shape of Figure 5.34(b), one match is found as shown in Figure 5.34(c). The execution of the match generates the design shown in Figure 5.34(d) – the shape that transitions from the transformation stage to the reconstruction stage.

The reconstruction stage consists of eleven shape rules that adapt this initial transformation from Entelechy I to reflect the organization of Entelechy II. The starting shape for this process is labeled with two triangles to ground the composition in one corner and allow for growth in two directions (Figure 5.35(b)). The labels are applied manually by the designer to establish two directions that correspond to the beachfront site of Entelechy II, so that one is parallel to the beach and the other is perpendicular. Reconstruction rule 1 (Figure 5.35(a)) is then applied to stretch the composition in one direction to enlarge the central space between figures, beneath the canopy above. This action can also be described in the schema $x \rightarrow t(x) + t(prt(x))$, where $t(x)$ defines the translation of the *LHS* shape and $t(prt(x))$ specifies the extension of the dashed lines to maintain their original point of connection with the rest of the outline. The application of this rule is depicted in Figure 5.35(c) to preview a single match. When implemented, the design of Figure 5.35(d) is generated. Reconstruction rule 2 (Figure 5.36(a)) then allows for the rectangular space at the dashed outline to be mirrored to the other side of the composition, described by the schema $x \rightarrow x + y$. A preview of the application of this rule to the elongated design (Figure 5.36(b)) results in one match as illustrated in Figure 5.36(c), with the resulting design given in Figure 5.36(d).

Once the stretch and mirror actions are taken, reconstruction rule 3 (Figure 5.37(a)) allows for the expansion of the module and addition of figures to grow the design to a desired width, to effectively stretch the composition in the other direction. This rule is conceptually similar to reconstruction rule 1 and can be described by the same schema,

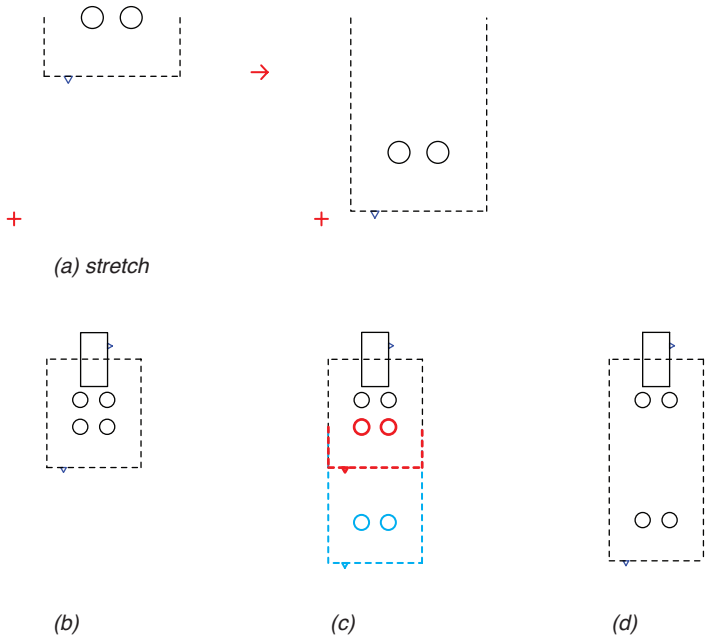


Figure 5.35 Entelechy II grammar – reconstruction rule 1: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

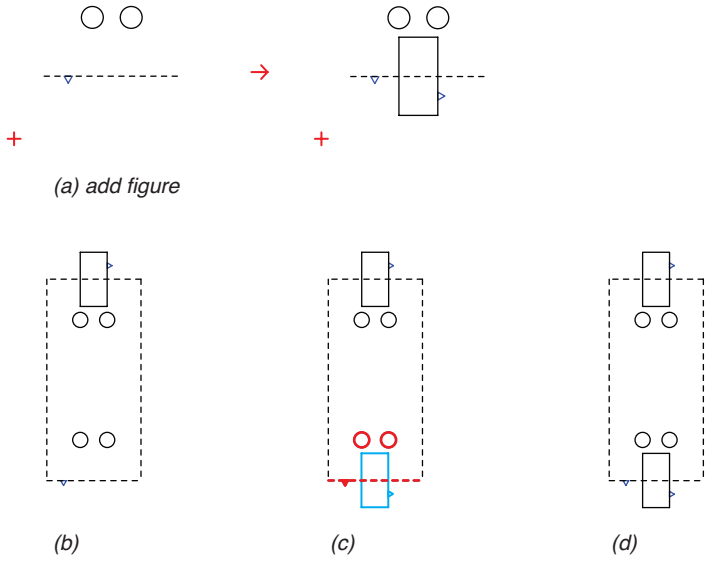


Figure 5.36 Entelechy II grammar – reconstruction rule 2: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

x → *t(x) + t(prt(x))*. For Entelechy II, the width is equal to five modules or six figural column spaces, requiring multiple applications of this rule. To preview this process, a single application of rule 3 to the design of Figure 5.37(b) is illustrated to show the two matches produced with each application of the rule (Figure 5.37(c)). When both matches are applied (as they must be to maintain a closed rectilinear outline), the arrangement expands one bay at a time as given in Figure 5.37(d). Four recursive applications of the

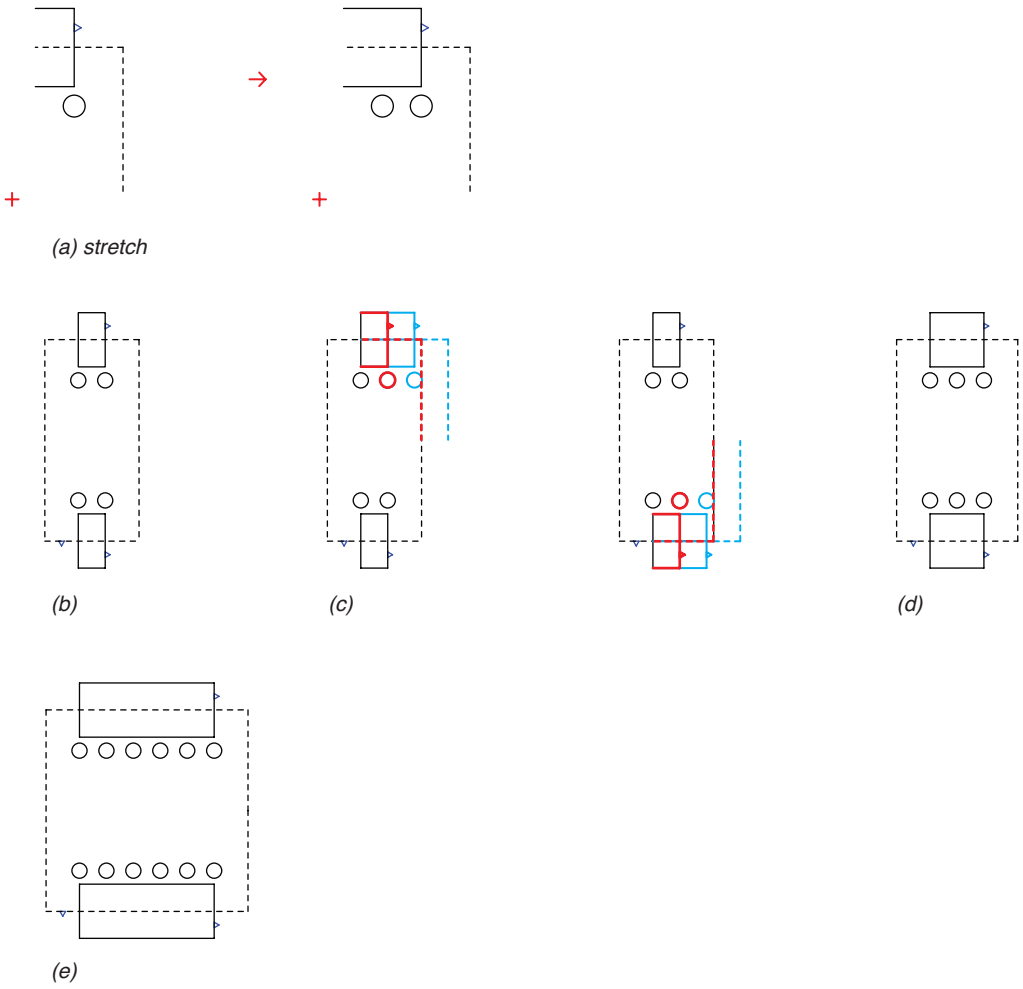


Figure 5.37 Entelechy II grammar – reconstruction rule 3: (a) rule; (b) initial shape; (c) rule matches; (d) design produced after one application; and (e) design produced after three more recursive applications of the rule.

rule are needed to match the conditions of Entelechy II, as depicted in the resulting shape of Figure 5.37(e).

Once the design is expanded, reconstruction rules 4-7 are then applied to introduce a series of elements within the open central court of the design. First, rule 4 (Figure 5.38(a)) starts the definition of a water figure, an action described by the schema, $x \rightarrow x + y$, to introduce a new element. The application of this rule to the shape of Figure 5.38(b) produces one match and is applied once to introduce this element (Figure 5.38(c) and (d)).

Rule 5 (Figure 5.39(a)) then builds on this to expand the water figure across the width of the composition as described by the compound schema $x \rightarrow prt(x) + t(prt(x)) + y$, where *prt(x)* describes the stabilizing column figure, *t(prt(x))* describes the extension of the water figure, and *y* describes the addition of a labeled circle on the other side of the water figure, whose center maintains the same distance to the edge of the water court as the column figure. Four cycles of this rule are needed to match the width of Entelechy II when applied to the design in Figure 5.39(b), as previewed and implemented in Figure 5.39(c) and (d).

Then, reconstruction rule 6 (Figure 5.40(a)) is applied to the design of Figure 5.40(b) to end the definition of the water figure as previewed in Figure 5.40(c) and applied in Figure 5.40(d). This rule is logically similar to rule 5 and maps to the same compound schema. Rule 7 (Figure 5.41(a)) follows to place circular column figures along the water figure as characterized by the general replacement schema $x \rightarrow y$. When applied to the design of Figure 5.41(b), six matches are found for the application of this rule, one of which is previewed in Figure 5.41(c). When all six are applied in parallel, the design of

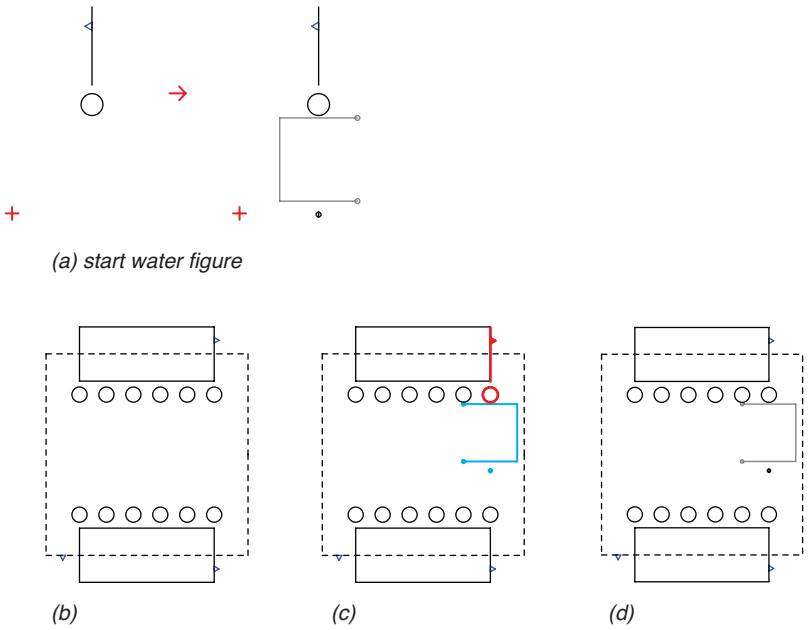


Figure 5.38 Entelechy II grammar – reconstruction rule 4: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

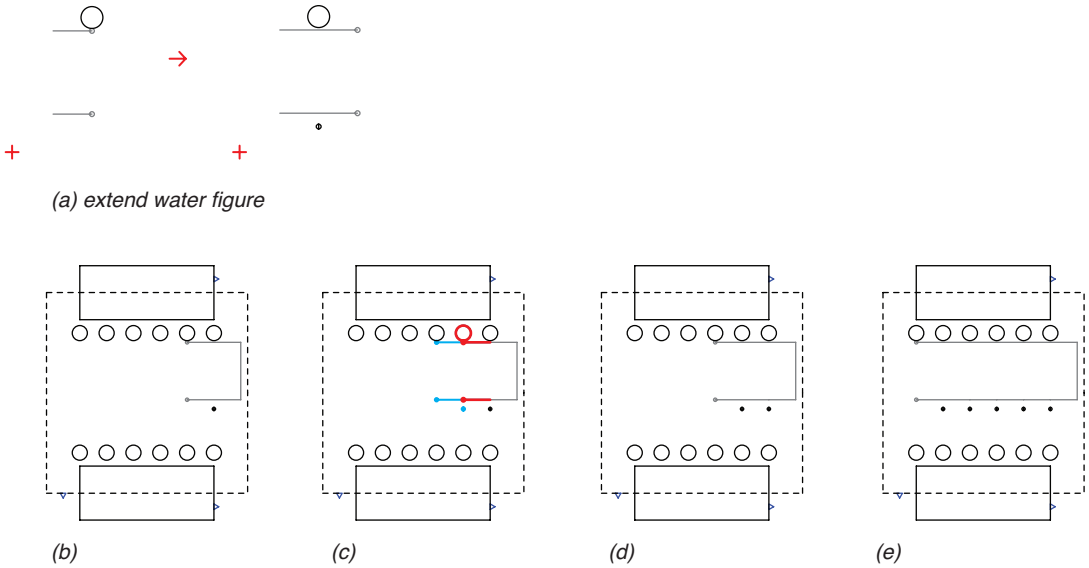


Figure 5.39 Entelechy II grammar – reconstruction rule 5: (a) rule; (b) initial shape; (c) rule match; (d) design produced after one application; and (e) design produced after three more recursive applications of the rule.

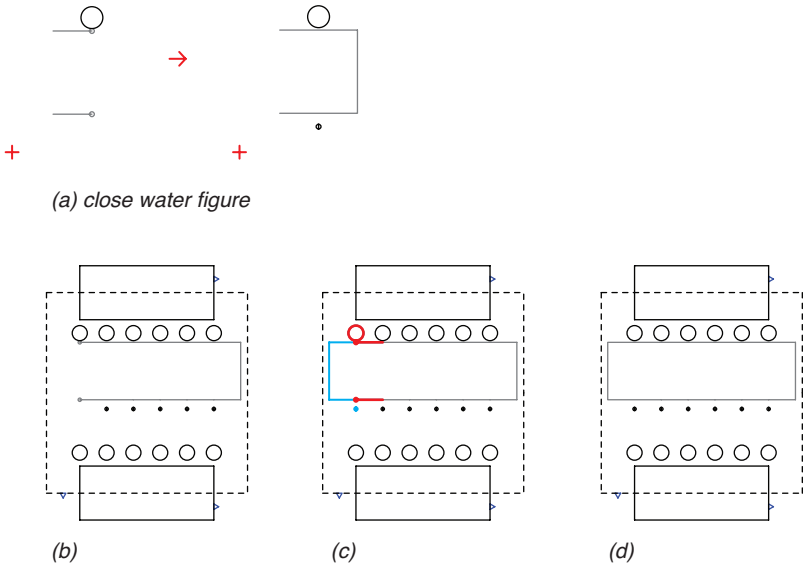


Figure 5.40 Entelechy II grammar– reconstruction rule 6: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

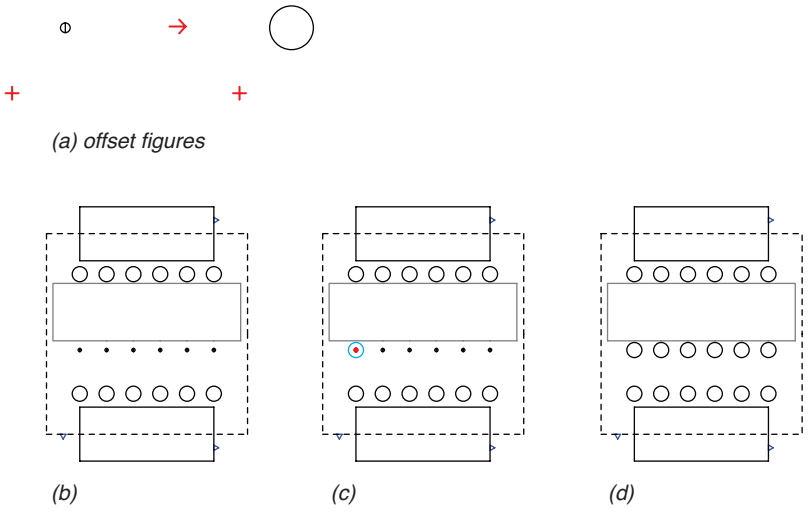


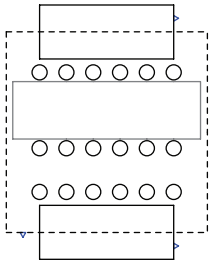
Figure 5.41 Entelechy II grammar– reconstruction rule 7: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application of all matches.

Figure 5.41(d) is produced, creating a third row of figures in the composition and a secondary axis of symmetry along the rectilinear water figure defining the edge of the central court.

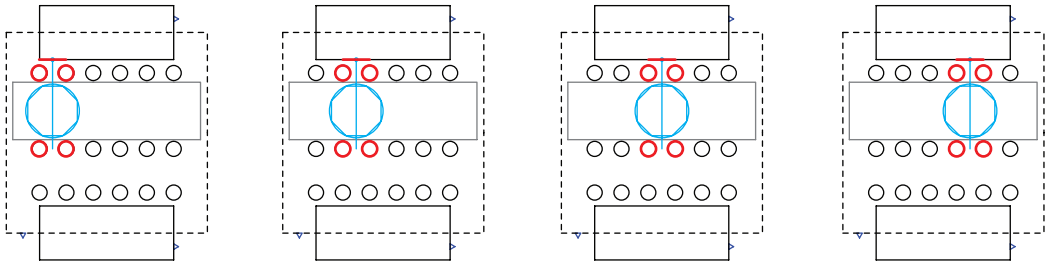
Reconstruction rules 8-11 are next, which introduce a circular space, cross axis, and entry figure to the design. All of these rules operate under the schema $x \rightarrow x + y$, so that the *LHS* shape of the rule, *x*, is always maintained in the *RHS* shape along with the addition of a new element and/or part of an element, *y*. Rule 8 (Figure 5.42(a)) initiates the circular space and allows for five possible applications when applied to the design of Figure 5.42(b). These matches each correspond to one interior bay of Entelechy II as illustrated in Figure 5.42(c). The fourth match in the first row of possibilities corresponds to Entelechy II and when this choice is applied, the design in Figure 5.42(d) is generated. Reconstruction rules 9 and 10 then extend an entry axis initiated by the choice of where to apply rule 8. When rule 9 (Figure 5.43(a)) is applied to the design of Figure 5.43(b), one match is found as given in Figure 5.43(c). The implementation of this match produces the design of (Figure 5.43(d). The application of rule 10 (Figure 5.44(a)) continues this process, resulting in two matches when applied to the shape of Figure 5.44(b), as shown in Figure 5.44(c). Both matches should be applied to extend the axis fully and achieve the design of Figure 5.44(d).

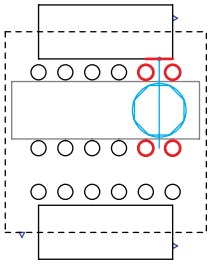
Rule 11 (Figure 5.45(a)) then locates the entry figure. A single match is found for this rule when applied to the design of Entelechy II in progress (Figure 5.45(b)), as previewed in Figure 5.45(c). When this rule is applied, the design of Figure 5.45(d) is generated, which completes the schematic generation of Entelechy II. To terminate the process, a single erasing rule is applied as a utility to remove the triangular labels that helped to guide the process.

(a) add figure

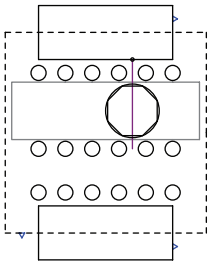


(b)





(c)



(d)

Figure 5.42 Entelechy II grammar– reconstruction rule 8: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

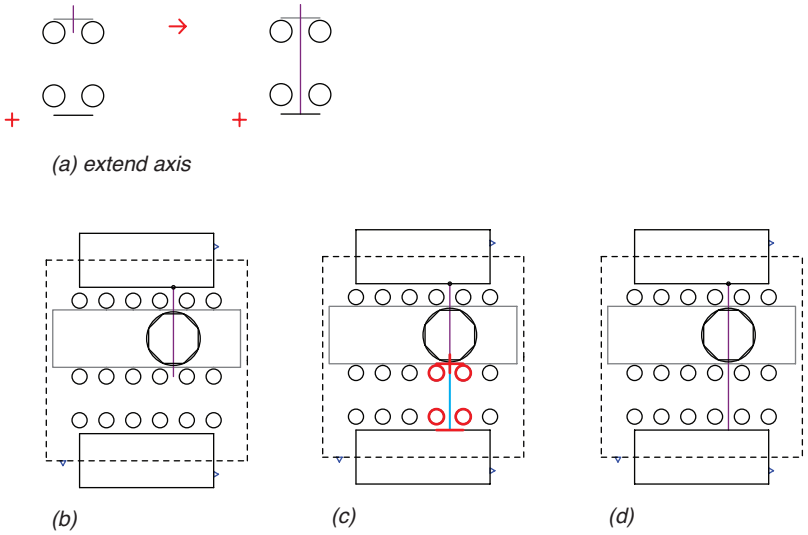


Figure 5.43 Entelechy II grammar– reconstruction rule 9: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

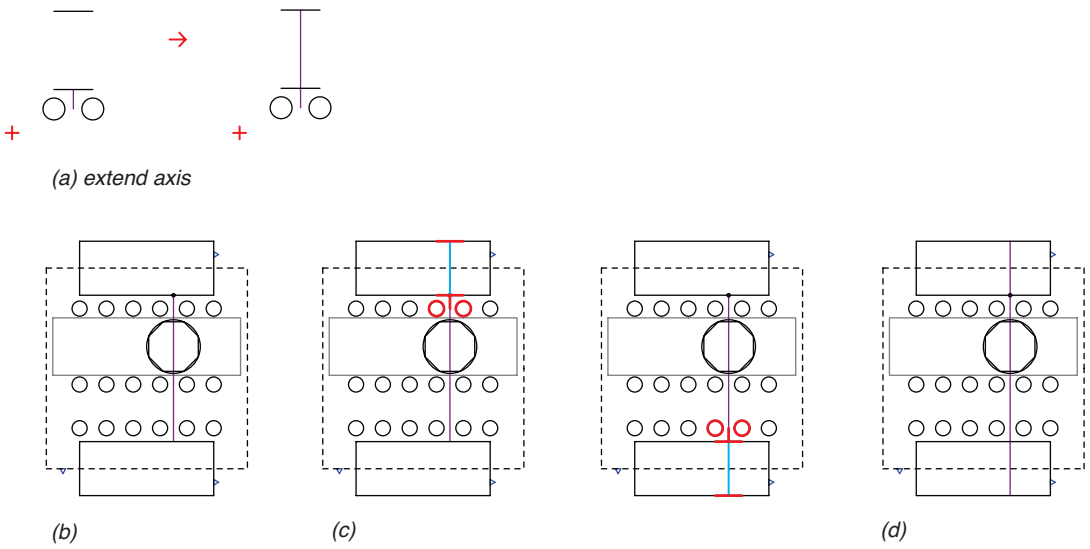


Figure 5.44 Entelechy II grammar– reconstruction rule 10: (a) rule; (b) initial shape; (c) rule matches; and (d) design produced after application.

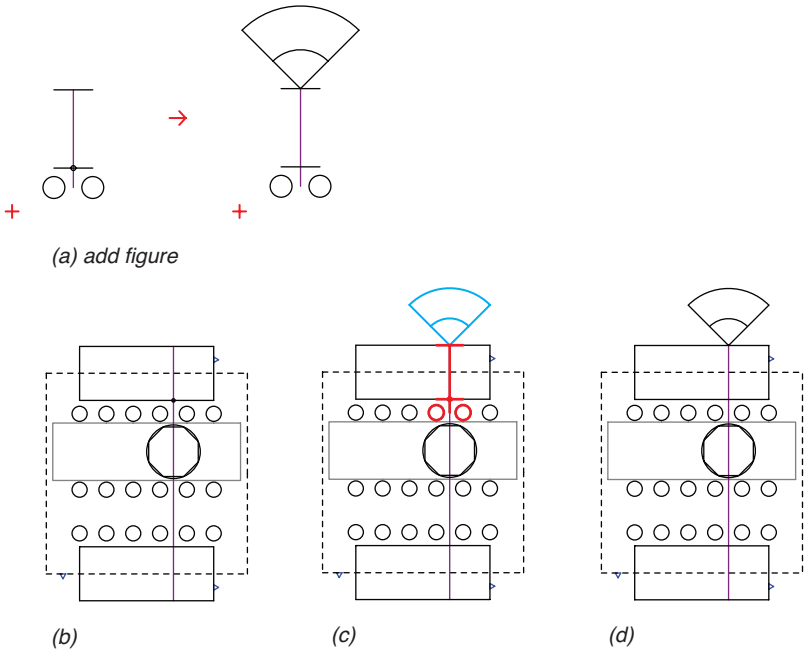


Figure 5.45 Entelechy II grammar – reconstruction rule 11: (a) rule; (b) initial shape; (c) rule match; and (d) design produced after application.

The identity, transformation, and reconstruction stages provide a structure for interpreting how spatial relationships in the organization of Entelechy I are reworked in Entelechy II. The revision of the domestic coordinate unit is explored with additional rulesets to adapt this interpretation for different designs, each calibrated to a residential context. A sample of possible Entelechy II variations is given in Figure 5.46. These sixteen house designs range from four columns in width in the first row, to five columns in width in the second row, to six columns in width in the third row, and finally, to seven columns in width in the fourth row. Each column of the catalog is also distinguished by the number of possible pavilions in each design, which decreases from left to right. The concepts most clearly specified in the rules are those of self-similarity, figure-ground reversal, and boundary ornamentation, as Entelechy II turns the domestic coordinate unit inside out to foreground the possibilities of exteriority at the beach house.

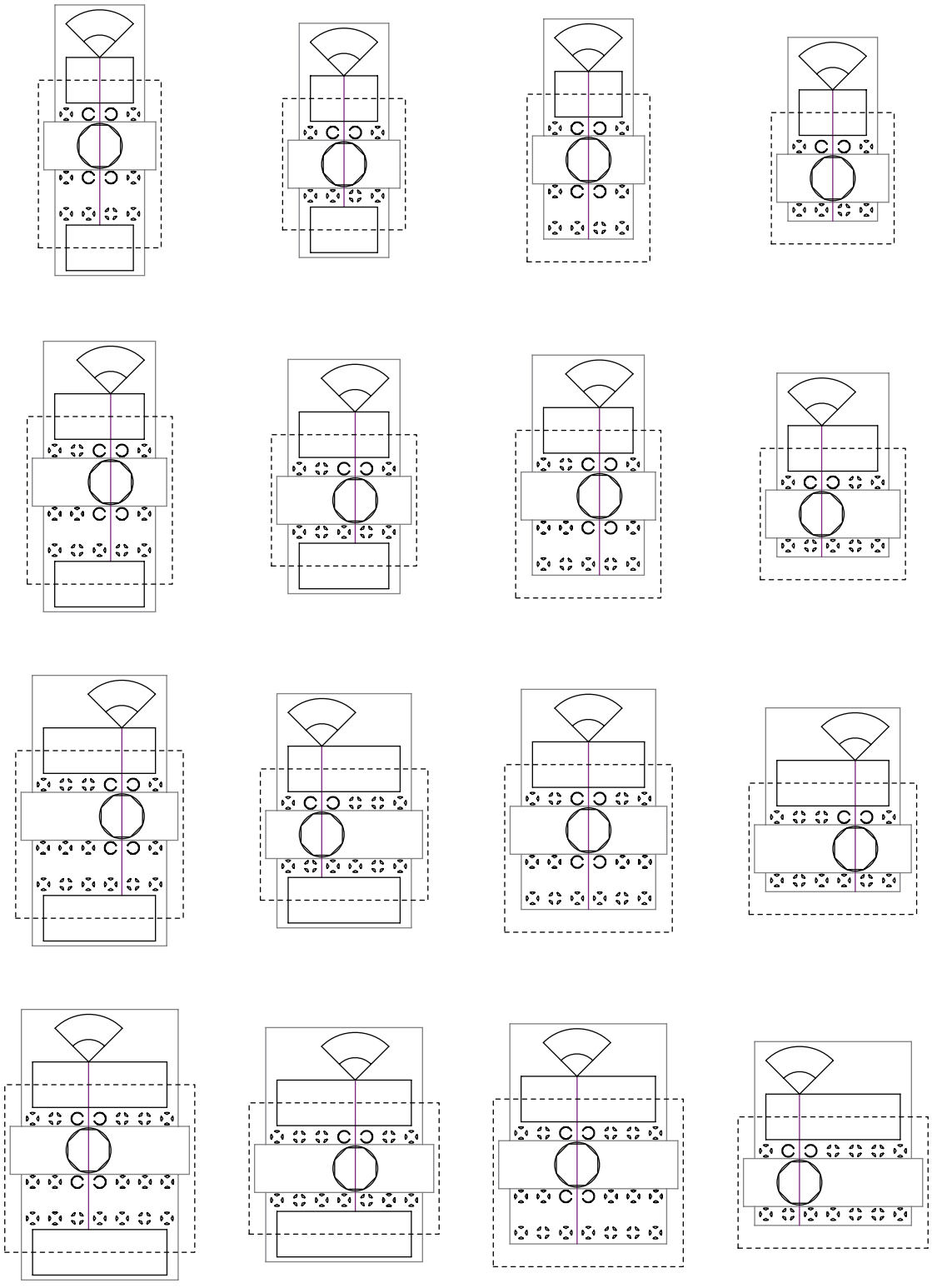


Figure 5.46 Entelechy II variations: catalog of sixteen design iterations generated in *Shape Machine*.

These variations share similarities with both the Portm-Ino variations of chapter 4 (Figure 4.28, Figure 4.29, Figure 4.30, and Figure 4.31) and the Renaissance Center variations in the previous section (Figure 5.30). The residential qualities are clearly distinct, and in their exaggeration and enlargement at the beach, they develop an urban quality, with groups of pavilions pulled apart to nearly resemble groups of buildings. This quality can be traced back through the shape rules used to generate all three original designs in the Entelechy, Renaissance Center, and Entelechy II grammars, each of which develops out of a conceptual parti of the domestic coordinate unit. In each of these interpretations, the same geometric system is developed to accommodate a different program, suggesting a paraphrase of the same question Wittkower (1949) asked of Palladio: What was in Portman's mind when he experimented over and over again with the same elements?

5.6 Discussion

The Portman variations include four transformation grammars to address the relationship between Entelechy I and the broader corpus presented in chapter 3. Specifically, the four contexts include: a) interior design in the Midnight Sun grammar; b) hospitality design in the Atrium Hotel grammar; c) urban design in the Renaissance Center grammar; and d) residential design in the Entelechy II grammar. In each case, transformation grammars were developed with three stages to focus on identity, transformation, and reconstruction as addressed within each context. All of the studies utilize shape rules implemented in *Shape Machine* to develop, verify, and build on an understanding of spatial relationships that connect the corpus to Entelechy I to interpret how Portman's narrative on the house as a carrier of architectural principles can be understood formally. These possibilities are plural and partial, but they demonstrate how

Portman's work can be seen in pursuit of an architecture that is committed to a notion of spatial organization that is systematic in the sense that it is amenable to change, replacement, exaggeration, and evolution.

It is with this understanding that the work can be seen as "living" – and evokes a series of recursive design principles, first introduced to describe shape rules of the Entelechy grammar in the concluding discussion of chapter 4. These principles establish form as their main vehicle and enterprise, so that they can be better understood as compositional approaches that focus on: a) *Platonic geometries*; b) *self-similarity*; c) *figure-ground reversal; d) boundary ornamentation*; and e) *offset forms*. It is these particular compositional approaches and obsessions in Portman's work that characterize his formal language and efforts to generate a body of coordinated, living forms. And this is not as a matter of elements or vocabularies, but one of formal relations and arrangements that can be systematically applied elsewhere as achieved here with shape rules and schemata - and all can be traced back to Entelechy I.

Platonic geometries is a principle defined in rules that specify an elementary set of shapes, for example the circle, the square, and the rest of the regular polygons, as the primary geometries to be applied in combinations that produce more complex and emergent forms. In Entelechy I, this principle is defined with the conceptual move to replace the solid column with a circular minor figure, in contrast to the square organization of the major grid. This circular figure is further articulated in eight parts, four of which are stable, and another four that can be exchanged for an empty figure as desired, to essentially remove parts in the larger arrangement. This same formal condition is repeated in Entelechy II, and the figure replacement schema, $x \rightarrow y$, appears in the remaining three transformation grammars to illustrate this principle at varying levels of detail. For example,

in the Atrium hotel and Renaissance Center grammars, Platonic geometries are employed compositionally at a conceptual level in terms of an overall massing (for example, in the rules of Figure 5.12, Figure 5.18, and/or Figure 5.23). In all cases, these substitutions privilege the exchange of Platonic geometries to define variable compositions within a similar set of shapes – primarily, circles, squares, and octagons in the corpus studied here.

Self-similarity is a principle distinguished in rules that provide an identical structure for modular change and growth, rendering designs and their parts as replicas across scales and functions. In Entelechy I, the commitment to the domestic coordinate unit as a structural organization and the hollow column as an element deployed iteratively set the foundation for this principle. This principle is captured in multiple schema, including $x \rightarrow t(x)$; $x \rightarrow x + t(x)$; $x \rightarrow x + prt(x)$; $x \rightarrow x + prt(x)$; as well as the composite $x \rightarrow x + t(prt(x))$. The *RHS* shape described in each of these schemata is modified to include transformations, copies, parts, and their combinations. In all of the transformation grammars, these actions are embedded in the structure established in relation to Entelechy I, whether through identity to the hollow column (Figure 5.1 and Figure 5.10) or to the conceptual parti of the domestic coordinate unit (Figure 5.21 and Figure 5.31). In the Renaissance Center and Entelechy II grammars, these schemata are particularly impactful due to the contextual challenge of designing for a group of buildings in an urban context and the group of pavilions in the residential retreat of the beach house.

Figure-ground reversal is a principle rendering rules that focus on the figure-ground relation as a context for inversion and adaptation to produce designs that are ambiguous, unsettling, and familiar. In the broader corpus of works considered, this principle is convincing in the Atrium Hotel grammar, where the definition of the corner that relates to the Hyatt Regency O'Hare (Figure 5.18) inverts the corner from its relation to one figure-

ground relation, x, to its distinction as a separate figural massing, y, as captured in the replacement schema, $x \rightarrow y$, to exchange the *LHS* shape, *x*, with a different RHS shape, *y*. The result is a distinctive figure-ground relation that can be further studied in the atria variations based on this prototype given in column 2 of Figure 5.20. At Entelechy II, the reversal of figure-ground relations is exaggerated to decouple the corner expression of the domestic coordinate unit from adjacent forms, inverting the relationships described above, and in effect, producing a detached corner condition as introduced in the process described in Figure 5.33.

Boundary ornamentation is a principle displayed in rules that decompose solid barriers between spaces and foster new connections through articulated ends, thresholds, and corners. In Entelechy I, this principle is exhibited in the sinuous façade that resists demarcation and the exploded column, an element Portman describes as "fragmented" in its pursuit to "break the mold of compressed architecture" (1997). This principle can be found in all four contexts modeled in the Portman variations and, especially, in the transformation stage of the Atrium Hotel grammar, where the part schema, $x \rightarrow prt(x)$, is utilized to translate from the circular figure of Entelechy I to the edge-corner parti achieved in Figure 5.16(b). Even more, the definition of the corner provides the primary formal distinction of three hotels in the corpus. For purposes of simplicity, all three corner rules (Figure 5.17, Figure 5.18, and Figure 5.19) were described by the replacement schema, $x \rightarrow y$, to unify their conceptual interest in the same corner *LHS* shape, *x*, with a different RHS shape, *y*. In the Midnight Sun grammar, ornamental boundaries are implied from the start, as the initial shape is the subdivided figure from Entelechy I and the entire production process maintains an organizational relationship to that beginning. Similarly, in the Renaissance Center and Entelechy II grammars, boundary ornamentation is already

embedded in the structure of the conceptual coordinate unit extracted from the Entelechy grammar as an initial shape and basis of production.

Offset forms is a principle established in rules that thicken conditions driving the development of nested solids and voids to privilege volumetric relations that negate straightforward interpretations of interiority and exteriority. In Entelechy I, this principle is put forward primarily in the hollow column as an offset structural element, defining Portman's concept of "space within space" as a structural, volumetric condition (Portman and Barnett, 1976). The Midnight Sun grammar elaborates how this approach translates to address Portman's concept of "space modulation" (Portman and Barnett, 1976), with two modules of seating first articulated as a rhythm at the boundary (Figure 5.4), an action that can be described by a part and addition schema, $x \rightarrow prt(x) + y$, to convey the introduction of a second module within the parts of the first. The replacement rules for seating and circulation demonstrate how this principle carries out in the details of an interior space, where the offset action defines key details of the furnishings as well (Figure 5.5, Figure 5.6, and Figure 5.7). And in the Atrium Hotel grammar this principle translates to monumental proportions in the offset that organizes the formal structure of the atrium, for example as a square-within-a-square (Figure 5.13).

What this all amounts to is a deliberate and steady interest in formal operations in Portman's work. Through the lens of Entelechy I, these principles are not paradoxical, but unified and overlapping, suggesting a language that is *coordinated* in the sense that it is studied, reworked, and purposefully amenable to changes based on a similar logic of organization. Even more, the language is intended to be recognized as a signature effort – and not in terms of specific elements or typologies, but in terms of formal relations and operations that are productive. The exploitation of the atrium in Portman's work has

already attracted a reading of repetition that foregrounds a developer-driven mindset in its purpose, but here, a rule-based interpretation has established a formal intent that is algorithmic and recursive in nature. In addition, the visual automation of this theory has demonstrated how variations are generated out of these principles – and how shape grammars and *Shape Machine* provide a medium for this purpose.

5.7 Summary

Four transformation grammars were presented to build on the rule-based interpretation of Entelechy I established in chapter 4. Each grammar is implemented in *Shape Machine* to further iterate on how the design philosophy embedded in Entelechy I can be viewed as a productive resource for understanding a broader corpus of Portman's works in terms of variations. The transformation grammars address the remaining corpus introduced in chapter 3 to explore four contexts, including: a) interior design in the Midnight Sun grammar; b) hospitality design in the Atrium Hotel grammar; c) urban design in the Renaissance Center grammar; and d) residential design in the Entelechy II grammar. Through a closer study of specific shape rules and schemata in each transformation grammar, five design principles were presented to characterize Portman's algorithmic, coordinated approach to form.

CHAPTER 6. CONCLUSION

By engaging a rule-based, visual approach to Portman's architecture, a new theory on his forms and their contributions was presented. This work is motivated by Portman's mythology on Entelechy I as a design generator and the opportunity of shape grammars as a methodology that celebrates the ability of shape computations to facilitate novel descriptions, interpretations, and evaluations in design. Significantly, this approach to architectural theory is based on shape rules developed independent of the original design process and therefore decoupled from the initial designer too. The broad view on Portman's formal language offered in the research aims to "re-cognize" (Goodman, 1978) the repetition in Portman's designs as a deliberate act toward a philosophy that can be read directly in his forms. In this way, the forms "live."

The methodology used to unpack this notion of living form depends on the vital qualities of shape, which "live" in the same way. This non-indexical, versatile, maximal attribute, unique to lines, planes, and solids, enables visual computations where design intuitions can be modeled, tested, and automated. Perhaps this makes art a science:

> Science is knowledge which we understand so well that we can teach it to a computer; and If we don't fully understand something, it is an art to deal with it. (Knuth, 1974).

The intent of this dissertation has been to ask how a design language and related architectural theory can be computationally represented, modeled, and deployed in a visual fashion, making the analysis of a language of designs a formal, generative pursuit. The task now is to go the other way – seeing things anew, from generation to art.

6.1 Future Directions

Directions for further study are motivated by the findings and contributions of the dissertation as well as its limitations, which together suggest how this work can continue. Five trajectories are proposed, each corresponding to one of the primary contributions. More precisely, the future directions of research address these areas: a) critical assessment; b) implemented shape grammars; c) implemented transformation grammars; d) shape rule schemata as interpretive devices; and e) *Shape Machine* for design analysis and generation.

6.1.1 Critical Assessment

The critical compilation of perspectives on Portman's architecture presented in chapter 2 encompass various background narratives and interpretations. However, they share an emphasis on Portman's designs from the years 1964-1986 – and this same early corpus in the United States is the focus of this dissertation. This corpus covers much ground, but it leaves plenty of open questions on Portman's work that are not addressed. Three are suggested here. First, the studies in chapter 5 foreground the big picture of variations in Portman's work. Each of these case studies (and more on this period of work) could be developed in far greater detail to test the claims made here on the language. Second, his later international work, especially in China, India, and Singapore is untouched in scholarship, formal or otherwise. The work here provides a basis for contrasting these later developments and how various cultural contexts are accommodated. Third, Portman's artistic production is not fully addressed here. Portman was a prolific painter, sculptor, and furniture designer – none of which is acknowledged in the scope of this study. These works are particularly interesting in how they illustrate

Portman's formal ideas, creative process, and sense of humor. Craig (2009) has assessed some of this work, but it could be reinterpreted algorithmically and perhaps in relation to the interpretations on Entelechy I and the broader corpus developed in this research.

6.1.2 Implemented Shape Grammars

The Entelechy grammar develops a systematic understanding of Portman's 1964 house as an implemented shape grammar. This method, where shape grammars are implemented in *Shape Machine*, provides a generous context for new pedagogies in design education and formal research. Curricula studying languages of designs, style, building typology, ornament, architectural history and more can be built on the foundation of this work, continuing the trajectory of the shape grammar discourse. Significantly, these future works can privilege new ways of considering analysis and synthesis utilizing *Shape Machine* as an intuitive environment for visual, algorithmic design exploration. The current work is limited by two-dimensional geometries (lines and arcs) and Euclidean transformations (primarily isometry and similarity). However, the software will be developed further, with additional geometries and transformations to increase capabilities for further study. In my own work, I'm interested in studying Anni Albers textile designs through this approach and think that an investigation of this work can also lead to novel ideas for rule-based pedagogies and curriculum development.

6.1.3 Implemented Transformation Grammars

The transformation grammars presented in chapter 5 study variations in a language of designs through implemented shape grammars. This notion of variation across scales and programs is somewhat schematic here, although the design variations are produced in *Shape Machine* with more developed rulesets beyond the scope of the

dissertation. These transformation rules could be developed even more to elaborate details relevant to architectural practice, suggesting how implemented transformation grammars might bridge from analysis to design in a professional context. In addition, this method can also influence future design curricula and related research trajectories, building on the suggestions of implemented shape grammars in the previous section. I'm interested in applying this method to study Anne Tyng's adaptation of a traditional wood frame house into a space frame structure in the Walworth Tyng project. I think the study of this particular transformation may be relevant for applying transformation grammars to formalize structural-spatial adaptations in design. These transformations may prove useful both for contemporary design interventions as well as for developing interesting problems and related approaches in studio-based design courses.

6.1.4 Shape Rule Schemata as Interpretive Devices

The assessment of shape rules via schemata that parse the logic of a shape rule is proposed in this research as a way to correlate predicates and transformations in the grammars with shared design approaches. Here, this reinforces the evaluation of Portman's work as algorithmic and recursive, specifically in terms of the use of Platonic geometries, self-similarity, figure-ground reversal, boundary ornamentation, offset forms, and their combinations. Essentially, this foregrounds the common algorithms of the work by applying shape rule schemata in an interpretive and evaluative role, suggesting future work that might address which algorithms persist over time in a larger context beyond Portman or any specific designer. In this sense, a study of a shape rule schemata might be proposed, for example one that embeds a space within another space, as the means to study nested forms and volumes across cultures and chronologies.

6.1.5 Shape Machine for Design Analysis and Generation

The constructive cycle of design propositions and evaluations achieved in *Shape Machine* to mechanically execute line drawings in an automated environment is a prototype setup offered in this work that can be foundational for future studies. Here, this is applied to illustrate shape computation as a productive, analytical, visual medium to enliven architectural theory through design generation. The use of *Shape Machine* in these studies has radically transformed the work, sharpening the use of shape rules and their productions, which I attribute largely to the feedback and partnership offered by the machine. This mechanical design interaction stimulates both reflection and back talk (Schön, 1983; Simon, 1996). A key issue and question of the current work is how best to represent and share this interaction. The research lays out a process for computational approaches in the study of architectural history and theory, but it is not yet clear how this can be best disseminated. What is clear is that the work suggests new kinds of software-enriched architectural scholarship that might allow readers to interact with design theory in novel and generative ways. Future work aims to address this issue by looking to contemporary platforms for scholarship that engage multi-media in their publications.

In addition, after working with *Shape Machine* over these two years of development, I'm interested in how this technology can empower alternative modes of design analysis and generation in architectural practice. The hotel iterations in chapter 5 (Figure 5.20) are a first step in thinking this through. Future work in this vein focuses on how a rule-based, visual approach to generative design descriptions can formalize best practices, leading to workflows where repetitive design tasks can be implemented or recorded as custom programs. An initial idea outside the scope of the dissertation that addresses this area in

my work is a current proposal for the generative redesign of existing buildings that aims to apply the notion of variation earlier in the design process for strategic interventions.

6.2 Final Notes on Entelechy

Portman picked up on the concept of *entelechy* to address his reading of his first home as a container of his architectural philosophy, a perpetual resource for formal composition in his designs, and an emblem of his interest in coordination as a means of generating living forms. In the 1976 book, *The Architect as Developer*, Portman does not discuss entelechy or use it as a proper name for the house. It is only much later, in the 1997 book on the beach house, *An Island on an Island*, where he discusses the term in reference to his two homes: Entelechy I (1964) and Entelechy II (1986), suggesting that the concept was articulated and refined in retrospect, after several years of designing projects – and putting him unexpectedly among the critical vitalists, like Bergson and Driesch, who opposed the mechanical, deterministic interpretation of nature to instead favor a margin of animated incalculability in things, a life principle that Driesch also described as 'entelechy' (Bennett, 2010: 63).

In Emersonian terms, this life principle could be associated with the individual and nature. So, substance (ούσία *ousia*) might be thought of as the spirit of the individual, and complete reality (έντελέχεια *entelecheia*) might translate to the cyclic structure of nature,

> And all the uses of nature admit of being summed in one, which yields the activity of man an infinite scope. Through all its kingdoms, to the suburbs and the outskirts of things, it is faithful to the cause whence it had its origin. It always speaks of Spirit. It suggests the absolute. It is a perpetual effect. It is a great shadow pointing always to the sun behind us. (Emerson, [1836], 2000: 40).

This excerpt comes from Emerson's essay, *Nature*, which is also the source of the quotation in the epigraph, which emphasizes the eye as the human tool for studying the cyclic structure of nature to delight in the beauty and pleasure of forms of life.

This life principle is here elaborated in terms of form to foreground Portman's architecture as recursive and computational. This rule-based approach emphasizes Portman's design language as one particularly interested in systematic compositions dependent on Platonic geometries, self-similarity, figure-ground reversal, boundary ornamentation, offset forms, and their aggregation in more complex designs. It is this interest in both simple order and accumulated variety that yields Portman's paradoxical forms, leading to competing characterizations and multiplicity in interpretation. By engaging the designs directly to reframe an understanding of the work, these characterizations can be understood as byproducts of the interest in flexibility and adaptation inherent to the work, here proposed as a "life principle" balancing both precise intent and emergent intuition.

6.3 Epilogue

During the course of developing this research, Portman participated in conversations with me on the project. These discussions abruptly ended when he passed away on December 29, 2017. While he was living, I met with him to talk about early manual versions of the shape grammar on Entelechy I, so he had some understanding of the project. At first, he was skeptical. We knew each other well because I had worked as an architect in his office for six years before I began my graduate studies at Georgia Tech. The last two years of that tenure I worked on a project where I spent nearly every afternoon with him at the central table in the office where he held his sketching sessions on current

projects. During those afternoons, he would draw on tracing paper with a big black marker on top of renderings, plans, sections, elevations, while talking about design and quoting Emerson, Gertrude Stein, Plato, Frank Lloyd Wright, and Scarlett O'Hara from Margaret Mitchell's *Gone with the Wind* (1936) – the Scarlett quotes were some that few in the office could follow, but as a fellow Atlantan, I could share in their humor. My job was to talk about the project over drawings and design issues, then discuss them with the team, consultants, etc. and return the next day with a revised underlay for the next round of the conversation. He was in his eighties then and his routine was a well-formed habit. He came to the office religiously, six days a week, after lunch, and was out by five to make it home for the evening. He spent his mornings attending to other business, but the afternoons were for design.

I think his initial skepticism toward my research was simply because it felt too close and too personal. Portman was an incredible optimist, but he took his work seriously and the mixed criticism he received throughout his life seemed to take its toll. As a result, he focused on his work. I was nervous about presenting my research to him as I developed a tremendous respect for him while I worked in his office. Despite his reservations, which he vocalized, he was gracious to meet with me on this project and have conversations on the research. I brought him papers to read on shape grammars – specifically we had conversations on the language of Palladian villas (Stiny and Mitchell, 1978) and Frank Lloyd Wright's prairie houses (Koning and Eizenberg, 1981). When I published my first conference paper on Entelechy I (Ligler and Economou, 2015a), I brought him a copy of the proceedings and he invited me for another meeting. The journal paper that developed out of that initial work on the house was published in print after his death, but he read it before the manuscript was submitted (Ligler and Economou, 2018). That paper earned

his trust. He encouraged me to keep going, to tell it as I see it, independently, while also offering to meet as much as I'd like to support the project. We ran out of time, but that freedom was invaluable to me. That's the kind of person he was: he believed in the integrity of the individual voice and that our contributions are the best gifts we can give. This project is my take on his work and it is motivated by my own direct experience as an architect designing with Portman as well as by my interest as a researcher in architecture and design computation.

REFERENCES

"About the Prize," The Pritzker Architecture Prize. Available at https://www.pritzkerprize.com/about

Exploded Columns Enclose Space within Space, 1965. In *Architectural Record: Record Houses of 1965* (pp. 126-129).

Architect's Home is Unique Expression of Space and Form: Architecture and Interiors by John C. Portman, 1970. *Architectural Digest, Winter,* 86-97.

At Home with John Portman - Circles in the Square, 1982. *Interior Design, March,* 160-167.

Abrams, M. H., 1953. *The mirror and the lamp: romantic theory and the critical tradition*. New York,: Oxford University Press.

Adams, R. P., 1957. Architecture and the Romantic Tradition: Coleridge to Wright. *American Quarterly, 9*(1), 46-62.

Aristotle, & Tredennick, H., 1933. *Aristotle in 23 Volumes.* Cambridge, MA: Harvard University Press.

Barnett, J., 1966. John Portman: Atlanta's One Man Urban Renewal Program. *Architectural Record.* 139, 1, 133-140.

Barnett, J., 1974. *Urban Design as Public Policy: Practical Methods for Improving Cities*. New York: Harper Collins.

Barnett, J., 1986. *The Elusive City: Five Centuries of Design, Ambition, and Miscalculation*. New York: Architectural Record Books, a McGraw-Hill publication.

Banham, R., 1960. *Theory and Design in the First Machine Age.* London: The Architectural Press.

Banham, R., 1976. *Megastructure: Urban Futures of the Recent Past.* New York: Harper and Row.

Benedikt, M. L., 1979. To Take Hold of Space: Isovists and Isovist Fields. *Environment and Planning B: Planning and Design, 6*(1), 47-65. doi:10.1068/b060047

Bennett, J., 2010. *Vibrant Matter: An Ecology of Things.* Durham and London: Duke University Press.

Bonner, J., 2017. Nine Persuasions Towards Architectural Pizzazz in the Work of John Portman. In M. Mostafavi (Ed.), *Portman's America & Other Speculations*. Zurich: Lars Müller Publishers.

Buelinckx, H., 1993. Wren's Language of City Church Designs: A Formal Generative Classification. *Environment and Planning B: Planning and Design, 20*(6), 645-676. doi:10.1068/b200645

Carpo, M., 2017. *The second digital turn : design beyond intelligence*. Cambridge, Massachusetts: The MIT Press.

Chase, S. C., 2002. A model for user interaction in grammar-based design systems. *Automation in Construction, 11*(2), 161-172.

Chase, S. C., 2010. Grammar based design tools: Issues of representation and interaction. *Slide presentation.* Available at https://vbn.aau.dk/ws/portalfiles/portal/57369300/DV_workshop_keynote_Chase.pdf

Chau, H.H., et al., 2004. Evaluation of a 3d shape grammar implementation. In J.S. Gero (Ed.), *Design Computing and Cognition '04*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 357-376.

Chomsky, N., 1957. *Syntactic structures*. The Hague: Mouton.

Cohen, P. S., 2017. Portmanian Architecture. In M. Mostafavi (Ed.), *Portman's America & Other Speculations*. Zurich: Lars Müller Publishers.

Coleridge, S. T., 1884. Shakespeare, a Poet Generally. In W. G. T. Shedd (Ed.), *The Complete Works of Samuel Taylor Coleridge* (Vol. IV). New York: Harper and Brothers Publishers.

Cook, P., 1968. The Hotel is Really a Small City. *Architectural Design, 38(1),* 90-94.

Cook, P., 1999. *Archigram.* Princeton: Princeton Architectural Press.

Colakoglu, B., 2005. Design by Grammar: an interpretation and generation of vernacular hayat houses in contemporary context. *Environment and Planning B: Planning and Design, 32*, 141-149.

Cover image, 1996. *The New Yorker*, July 22, 1996.

Craig, R. M., 1989. Mythic Proportions: The Portman Home. *Southern Homes, Jan/Feb,* 90-99.

Craig, R. M., 2009. *John Portman : art and architecture*. Atlanta: High Museum of Art.

Denny, P., 2018. Once Unfashionable, John Portman Is Being Seen in a New Light. *Metropolis.* Available at https://www.metropolismag.com/architecture/john-portman-legacy/

Downing, F., & Flemming, U., 1981. The bungalows of Buffalo. *Environment and Planning B: Planning and Design, 8*(3), 269-293

Duarte, J. P., 2005. Towards the mass customization of housing: the grammar of Siza's houses at Malagueira. *Environment and Planning B: Planning and Design, 32*(3), 347-380

Drexler, A.,1979. *Transformations in modern architecture*. Museum of Modern Art: New York.

Economou, A., 2018. The Six Vitruvian Principles of Architectural Design Reframed within Contemporary Computational Design Discourse, Nexus 2018 Architecture and Mathematics Conference Book, eds. K. Williams and M.G Bevilaqua, Kim Williams Books, University of Pisa, pp.117-121.

Economou, A., & Grasl, T., 2012. Spatial Sieves. In S. Kanach (Ed.), *Xenakis Matters: Contexts, Processes, Applications* (pp. 287-313): Pendragon Press.

Economou, A., & Grasl, T., 2018. Paperless grammars. In *Computational Studies on Cultural Variation and Heredity* (pp. 139-160): Springer.

Economou, A., Hong, K., Ligler, H., & Park, J., 2019. *Shape Machine: A Primer in Visual Composition.* Paper presented at the Cultural DNA: Computational Studies on Cultural Variation and Heredity, KAIST, South Korea.

Economou, A., & Kotsopoulos, S., 2014. From Shape Rules to Rule Schemata and Back. In: Gero J. (eds) Design Computing and Cognition '14. DCC 2014. Springer, 419-438.

Eisenman, P.,1983. Interview: John Portman and Peter Eisenman. *Skyline, January* 12.

Eloy, S., & Duarte, J.P., 2011. A transformation grammar for housing rehabilitation. *Nexus Network Journal, 13(1)*, 49-71.

Eloy, S., Pauwels, P., & Economou, A., 2018. AI EDAM Special Issue: Advances in implemented shape grammars: Solutions and applications. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 32*(2), 131-137.

Emerson, R. W., [1836], 2000. Nature. In B. Atkinson (Ed.), *The essential writings of Ralph Waldo Emerson*. New York: Modern Library.

Emerson, R. W., [1837], 2000. The American Scholar. In B. Atkinson (Ed.), *The essential writings of Ralph Waldo Emerson*. New York: Modern Library.

Emerson, R. W., [1841], 2000. Self-Reliance. In B. Atkinson (Ed.), *The essential writings of Ralph Waldo Emerson*. New York: Modern Library.

Emerson, R. W., 1841. Thoughts on Art. *The Dial*.

Flemming, U., 1981. The Secret of the Casa Giuliani Frigerio. *Environment and Planning B: Planning and Design, 8*(1), 87-96.

Flemming, U., 1987. More than the sum of parts: the grammar of Queen Anne houses. *Environment and Planning B: Planning and Design, 14*(3), 323-350.

Georgia Tech Alumni Association, 1951, *Georgia Tech Alumni Magazine*, *30*(02), 9.

Giamarelos, S., 2018. Calling Rowe: After-lives of Formalism in the Digital Age. *FOOTPRINT*, 89-102. doi:10.7480/footprint.12.1.1760

Gips, J., & Stiny, G., 1980. Production Systems and Grammars: A Uniform Characterization. *Environment and Planning B: Planning and Design, 7*(4), 399-408. doi:10.1068/b070399

Gips, J., 1999. Computer implementation of shape grammars. In National Science Foundation / Massachusetts Institute of Technology report, *Workshop on Shape Computation*, 1-11.

Goldberger, P., 1973. Portman's formula: big spaces, flamboyant forms. *The New York Times,* August 26, 1973. pp. 223.

Goldberger, P., 1974. *Hyatt Regency Atlanta, Georgia, 1967: Hyatt Regency O'Hare, Chicago, Illinois, 1971: Hyatt Regency San Francisco, California, 1973*. Tokyo: A.D.A.

Goldberger, P., 1985. Marriott Marquis Hotel: An Edsel in Times Square? *The New York Times,* August 31, 1985. Section 1, 25.

Goldberger, P., 2009. *John Portman : art and architecture*. Atlanta: High Museum of Art.

Goodman, N., 1978. *Ways of worldmaking*. Indianapolis,: Hackett Pub. Co.

Grasl, T., & Economou, A., 2010. Palladian Graphs: Using a graph grammar to automate the Palladian grammar. Future Cities, 28th eCAADe Conference Proceedings, Eds: G. Schmitt et al., ETH Zurich, Switzerland, 275-284.

Grasl, T., & Economou, A., 2011. *GRAPE: using graph grammars to implement shape grammars*. SimAUD: Simulation for Architecture and Urban Design, Boston, MA, 45-52.

Grasl, T., & Economou, A., 2013. From Topologies to Shapes: Parametric Shape Grammars Implemented by Graphs. *Environment and Planning B: Planning and Design, 40*(5), 905-922. doi:10.1068/b38156

Grasl, T., & Economou, A., 2018. From Shapes to Topologies and Back: An Introduction to a General Parametric Shape Grammar Interpreter. AI EDAM Special Issue: Advances in implemented shape grammars: Solutions and applications. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 32*(2), 208-224.

Gueft, O., 1965. 24 Hollow Columns and the Space Between Them. *Interiors, 124(9),* 89-99.

Hagberg, E., 2009. Man from Atlanta. *Wallpaper, W*129,* 178-188.

Hays, K. M., & Porter, A. S., 2017. The Theatrical Paradox of the Atrium. In M. Mostafavi (Ed.), *Portman's America & Other Speculations*. Zurich: Lars Müller Publishers.

Hong, K., & Economou, A., forthcoming. Shape Machine.

Huxtable, A. L., 1974. The New American City. *The New York Times,* May 5, 1974. pp. AL-21.

Jacobs, K., 2018. Learning to Appreciate John Portman. *Architect Magazine: The Journal of the American Institute of Architects.* Available at https://www.architectmagazine.com/design/learning-to-appreciate-john-portman_o

Jameson, F., 1991. *Postmodernism, or, The cultural logic of late capitalism*. London; New York: Verso.

Kahn, L., 1957. Order in Architecture. *Perspecta, 4*, 58-63. doi:10.2307/1566858

Kennedy, S., 1988. Architects Now Doubling as Developers. *The New York Times*. February 7, 1988, Section 8, Page 1.

Kikutake, K. et al., 1960. *Metabolism: The Proposals for New Urbanism.* Tokyo: Bijutsu shūpansha.

Knight, T., 1981. The Forty-One Steps: The Language of Japanese Tea-Room Designs. *Environment and Planning B: Planning and Design, 8*(1), 97-114. doi:10.1068/b080097

Knight, T., 1994. *Transformations in design : a formal approach to stylistic change and innovation in the visual arts*. Cambridge ; New York: Cambridge University Press.

Knight, T., 2003. Computing with emergence. *Environment and Planning B: Planning and Design, 30*(1), 125-155

Knight, T., 2014. Regarding rules: from Rimini to Rio. *Joelho. Revista de Cultura Arquitectónica*.

Knight, T., & Stiny, G., 2001. Classical and non-classical computation. *Arq: architectural research quarterly, 5*(4), 355-372

Knight, T., & Stiny, G., 2015. Making grammars: from computing with shapes to computing with things. Design Studies, 41, pp.8-28.

Knuth, D. E., 1974. Computer programming as an art. *Communications of the ACM, 17* (12), 667–673. doi:10.1145/361604.361612

Koning, H., & Eizenberg, J., 1981. The Language of the Prairie: Frank Lloyd Wright's Prairie Houses. *Environment and Planning B: Planning and Design, 8*(3), 295-323. doi:10.1068/b080295

Koolhaas, R., Mau, B., Sigler, J., Werlemann, H., & Office for Metropolitan Architecture, 1995. *Small, medium, large, extra-large*. New York, N.Y.: Monacelli Press.

Kopp, A., 1970. *Town and revolution; Soviet architecture and city planning, 1917-1935*. New York,: G. Braziller.

Krishnamurti, R., 1981. The Construction of Shapes. *Environment and Planning B: Planning and Design, 8*(1), 5-40. doi:10.1068/b080005

Krishnamurti, R., 1992. The Maximal Representation of a Shape. *Environment and Planning B: Planning and Design, 19*(3), 267-288. doi:10.1068/b190267

Krstic, D., 2001. Algebras and grammars for shapes and their boundaries. *Environment and Planning B: Planning and Design, 28*(1), 151-162.

Krstic, D., 2005. Shape decompositions and their algebras. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 19*(4), 261-276.

Lapidus, M., 1978. The Architect as Developer. *Journal of the Society of Architectural Historians, 37*(4), 303-305.

Le Corbusier [1926], 1970. Five Points Toward a New Architecture. In *Programs and Manifestos in Twentieth Century Architecture*. Cambridge: MIT Press.

Ligler, H., & Economou, A., 2015a. *Entelechy I: Towards a Formal Specification of John Portman's Domestic Architecture.* Paper presented at the Proceedings of the 33rd eCAADe Conference, Vienna, Austria.

Ligler, H., & Economou, A., 2015b. Lost in translation: Towards an automated description of John Portman's domestic architecture. *Blucher Design Proceedings, 2*(3), 657-661.

Ligler, H., & Economou, A., 2018. Entelechy revisited: On the generative specification of John Portman's architectural language. *Environment and Planning B: Urban Analytics and City Science, 45*(4), 623-648. doi:10.1177/0265813516676489

Ligler, H., & Economou, A., 2019a. On John Portman's Atria: Two Exercises in Hotel Composition. In: Gero J. (eds) Design Computing and Cognition '18. DCC 2018. Springer, Cham. https://doi.org/10.1007/978-3-030-05363-5_22

Ligler, H., & Economou, A., 2019b. From Drawing Shapes to Scripting Shapes: Architectural Theory Mediated by Shape Machine. SimAUD 2019 Conference Proceedings.

Lin, Z., 2011. Nakagin Capsule Tower: Revisiting the Future of the Recent Past. *Journal of Architectural Education, 65*(1), 13-32. doi:10.1111/j.1531-314X.2011.01158.x

Maki, F., 1964. *Investigations in Collective Form.* St. Louis: Washington University School of Architecture.

March, L., 1976(a). The logic of design and the question of value. In L. March (Ed.), *The Architecture of Form.* Cambridge: Cambridge University Press.

March, L., 1976(b). A Boolean description of a class of built forms. In L. March (Ed.), *The Architecture of Form.* Cambridge: Cambridge University Press.

March, L., & Stiny, G., 1985. Spatial Systems in Architecture and Design: Some History and Logic. *Environment and Planning B: Planning and Design, 12*(1), 31-53. doi:10.1068/b120031

Martin, R., & Baxi, K., 2007. *Multi-National City: Architectural Itineraries*. Barcelona: Actar, 21-22.

Martin, R., 2009. Money and Meaning: The Case of John Portman. *Hunch, 12*, 36-51.

McCullough, M., 2006. 20 years of scripted space. *Architectural Design, 76*, 12-15. doi:10.1002/ad.288

McKay, A., Chase, S., Shea, K., & Chau, H.H., 2012. Spatial grammar implementation: From theory to useable software. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 26*(2), 143-159.

Medina, S., 2017. John Portman is a “Renaissance Architect,” says Harvard GSD’s Mohsen Mostafavi. *Metropolis.* Available at https://www.metropolismag.com/architecture/portmans-america-book/

Mitchell, M., 1936. *Gone with the Wind*. Macmillan Publishers.

Mitchell, W. J., 1990. *The logic of architecture : design, computation, and cognition*. Cambridge, Mass.: MIT Press.

Mostafavi, M. (Ed.), 2017. *Portman’s America & Other Speculations*. Zurich: Lars Müller Publishers.

Muschamp, H., 1992. Architecture View: The Thrill of Outer Space for Earthbound Lives. *The New York Times,* September 20, 1992. Section 2, 30.

Petit, E., 2014. Spherical Penetrability: Literal and Phenomenal. *Log, 31*, 31-39.

Phillips, M. G., 2008. Framing What We See: The Role of Ornament in Structuring Louis Sullivan's Design Logic. *Environment and Planning B: Planning and Design, 35*(5), 772-793. doi:10.1068/b34021

Pólya, G., Tarjan, R. E., & Woods, D. R., 1983. *Notes on introductory combinatorics*. Boston: Birkhäuser.

Pope, A., 1996. *Ladders*. Houston; New Haven: Rice University School of Architecture and Princeton Architectural Press.

Portman, J, 1982. Architect as Developer. *Architectural Association (AA) Lecture Series*. Available at https://www.aaschool.ac.uk/VIDEO/lecture.php?ID=2843

Portman, J., Craig, R. M., & Castellano, A., 1997. *An island on an island*. Milano: L'Arca.

Portman, J. C., & Barnett, J., 1976. *The architect as developer*. New York: McGraw-Hill.

Rice, C., 2016. *Interior Urbanism: Architecture, John Portman and Downtown America*. New York: Bloomsbury.

Rowe, C., 1972. Introduction to *Five Architects*. New York: Wittenborn.

Rowe, C. [1947], 1976. *The mathematics of the ideal villa, and other essays*. Cambridge, Mass.: MIT Press.

Rutheiser, C., 1996. *Imagineering Atlanta: The Politics of Place in the City of Dreams.* New York: Verso.

Schön, D. A., 1983. *The reflective practitioner : how professionals think in action*. New York: Basic Books.

Simon, H. A., 1975. Style in Design. In C. Eastman (Ed.), *Spatial Synthesis in Computer-Aided Building Design*. New York: John Wiley & Sons.

Simon, H. A., 1996. *The sciences of the artificial* (3rd ed.). Cambridge, Mass.: MIT Press.

Siry, J., 1996. *Unity Temple : Frank Lloyd Wright and architecture for liberal religion*. Cambridge England ; New York, NY, USA: Cambridge University Press.

Sorkin, M., 1991. *Exquisite corpse : writing on buildings*. London; New York: Verso.

Steenson, M.W., 2017. *Architectural Intelligence: How Designers and Architects Created the Digital Landscape.* Cambridge, Mass.: MIT Press.

Stiny, G., 1977. Ice-Ray: A Note on the Generation of Chinese Lattice Designs. *Environment and Planning B: Planning and Design, 7*(1), 89-98. doi:10.1068/b040089

Stiny, G., 1980a. Introduction to shape and shape grammars. *Environment and Planning B: Planning and Design, 7*(3), 343-351.

Stiny, G., 1980b. Kindergarten grammars: designing with Froebel's building gifts. *Environment and Planning B: Planning and Design, 7*(4), 409-462.

Stiny, G., 1985. Computing with Form and Meaning in Architecture. *Journal of Architectural Education, 39*(1), 7-19.

Stiny, G., 1986. A New Line on Drafting Systems. *Design Computing, 1*, 5-19.

Stiny, G., 1990. What designers do that computers should. *The Electronic Design Studio: architectural knowledge and media in the computer era*, 17-30.

Stiny, G., 1996. Useless rules. *Environment and Planning B: Planning and Design, 23*, 235-237.

Stiny, G., 2006. *Shape : talking about seeing and doing*. Cambridge, Mass.: MIT Press.

Stiny, G., 2011. What rule(s) should I use? *Nexus Network Journal, 13*(1), 15-47

Stiny, G., 2015. The critic as artist: Oscar Wilde’s prolegomena to shape grammars. *Nexus Network Journal, 17*(3), 723-758

Stiny, G., & Gips, J., 1972. *Shape Grammars and the Generative Specification of Painting and Sculpture.* Paper presented at the Information Processing 71, Amsterdam: North-Holland.

Stiny, G., & Gips, J., 1978. *Algorithmic aesthetics : computer models for criticism and design in the arts*. Berkeley: University of California Press.

Stiny, G., & March, L., 1981. Design machines. *Environment and Planning B: Planning and Design, 8*(3), 245-255.

Stiny, G., & Mitchell, W. J., 1978. The Palladian Grammar. *Environment and Planning B: Planning and Design, 5*(1), 5-18. doi:10.1068/b050005

Stiny, G., & Mitchell, W. J., 1980. The Grammar of Paradise: On the Generation of Mughul Gardens. *Environment and Planning B: Planning and Design, 7*(2), 209-226. doi:10.1068/b070209

Sullivan, L., [1922], 1990. *A System of Architectural Ornament, According with a Philosophy of Man's Powers*. New York: Rizzoli, in cooperation with the Art Institute of Chicago.

Traubel, H., 1914. *With Walt Whitman in Camden* (Vol. 3). New York: Mitchell Kennerley.

Uechi, N. T., 2013. *Evolving Transcendentalism in Literature and Architecture: Frank Furness, Louis Sullivan, and Frank Lloyd Wright*. Newcastle upon Tyne: Cambridge Scholars Publishing.

Vitruvius, 1999. *The Ten Books on Architecture*. I. Rowland and T. Howe (Eds.); I. Rowland (Trans.). Cambridge: Cambridge University Press.

Whitman, W., 1855. *Leaves of grass*. Brooklyn, New York,.

Wittkower, R., 1949. *Architectural principles in the age of humanism*. London,: Warburg Institute, University of London.

Wordsworth, W., & Coleridge, S. T., 1798. *Lyrical ballads with a few other poems*.

Wright, F. L., & Princeton University. Department of Art and Archaeology, 1931. *Modern architecture; being the Kahn lectures for 1930*. Princeton, N.J.: Princeton University Press.

Wright, F. L., 1932. *An autobiography: Frank Lloyd Wright* (1st ed.). London, New York,: Longman's, Green and Co.

Wright, F. L., 1949. *Genius and the mobocracy* (1st ed.). New York,: Duell.

Wright, F. L., 1957. *A testament*. New York,: Horizon Press.

Young, A, 2018. Eulogy for John Portman. Available at https://www.atlantamagazine.com/news-culture-articles/andrew-youngs-eulogy-john-portman/